APPENDIX G1

WATER QUALITY AND QUANTITY

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This appendix covers both surface- and groundwater resources.

G1.1 SURFACE-WATER RESOURCES

G1.1.1 Affected Environment

G1.1.1.1 Physical Environment

This section briefly describes the physical and regulatory setting of surface waters that are potentially affected by the San Luis Drainage Feature Re-evaluation project. As discussed in Section 2, the drainage study area is located in western San Joaquin Valley and consists of the lands primarily lying within the boundary of the Central Valley Project's San Luis Unit. Potential discharge locations for the two out-of-valley disposal options include the Delta (Chipps Island or Carquinez Straits) and Point Estero located northwest of the city of San Luis Obispo. Physical and regulatory environment is discussed for each of these locations.

The study area is semiarid, characterized by hot, dry summers and mild winters. Summer temperatures may reach 110°F, while winter temperatures may fall below 25°F. The high summer temperatures and low relative humidity combine for a high rate of surface water evaporation.

G1.1.1.2 Existing Surface-Water Resources

Water supply for drainage study area is mainly derived from runoff from the mountains and foothills of the Coast Ranges and the Sierra Nevada foothills. The annual rainfall averages between 6 and 8 inches, with 90 percent of the amount falling during the winter between November and April. The primary use of water in the study area is for agriculture. Surface-water supplies have been developed by local irrigation districts, county agencies, and private companies, as well as by State and Federal agencies. The San Joaquin River is the main natural drainage for surface water but it has been augmented by various human-made drainage systems.

The San Joaquin River flows north and converges with the southerly flowing Sacramento River in the San Francisco Bay-Delta Estuary. From there the water flows through Suisun Bay and Carquinez Strait into San Francisco Bay (the Bay) and out to the Pacific Ocean. However, freshwater streamflows are depleted by irrigation diversions and subsequently increased by drainwater high in selenium (Se) and salts. Surface and subsurface agricultural drainwaters are the major source of salt in the lower San Joaquin River basin. This salt loading contributes to impairment of water quality in the lower San Joaquin River and the San Joaquin-Sacramento River Delta (Delta) region. The most heavily concentrated source of agricultural salt discharge to the Delta is the San Joaquin River. Agricultural drainwater has been estimated to carry as much as 740,000 tons of total annual salt into the Delta. Streamflows into the Delta are also influenced by tidal action further increasing the salt content. Natural tidal fluctuation and the resulting intrusion of seawater further increase the Delta's salinity.

The streams within the study area are intermittent, are often highly mineralized, and many have been recognized as having impaired water quality under Clean Water Act (CWA) Section 303(d). Over 130 miles of the main stem of the San Joaquin River downstream of Friant Dam are listed as water quality-impaired for salinity. The salt concentrations of water in the lower San

Joaquin River and south Delta frequently exceed desirable levels for agricultural and other beneficial uses. The 700 µmhos/cm specific conductance (or electrical conductivity) water quality objective (WQO) for the San Joaquin River near Vernalis for April to August has been exceeded over 50 percent of the time from 1986 through 1997 (Reclamation 2001).

Under certain high-flow conditions a major source of Se discharge to the Delta is the San Joaquin River. Median Se values in the river upstream from Vernalis occasionally exceed the U.S. Environmental Protection Agency's (EPA's) ambient water quality criteria of 5 micrograms per liter (µg/L) for protection of aquatic life (*Grassland Bypass Program Monitoring Program Quarterly Report*, SFEI 2002).

The existing surface-water quality is the result of four factors: climate, topography, geology, and irrigation. Surface agricultural runoff (tailwater discharges and stormwater runoff) contributes a portion of the salt load to the San Joaquin River and the Delta. Discharge of tailwater is prohibited by the Northerly Area water districts. However, salt in water supply and Se in stormwater run-on can represent a large percentage of the salt and Se in surface agricultural runoff. Irrigation water supply quality is, therefore, one key factor in determining surface agricultural runoff quality.

Subsurface drainage is a more concentrated source of salt than surface runoff. Discharge of subsurface drainage is occurring through the Grassland Bypass Project, which conveys drainage from the Northerly Area to Mud Slough and on to the San Joaquin River.

Se is a semimetallic trace element that is widely distributed in the earth's crust at levels less than 1 milligram per kilogram (mg/kg) and with chemical properties similar to sulfur. The natural source of Se in San Joaquin Valley is erosion of the marine shales in the eastern side of the Coast Range mountain soils, followed by deposition of sediment in the valley, which forms the parent material for valley soils. Accelerated transfer of Se into the valley aquatic ecosystem occurs when Se-bearing materials are subject to floods, or disturbed by road building, mining, overgrazing, and agricultural irrigation.

Irrigation water applied to agricultural lands in western San Joaquin Valley can leach Se from the soil to the shallow groundwater. Tile drains have been installed on some farms to reduce the harmful effects of salts reaching the root zone. However, these drains have unintentionally accelerated the leaching of Se into the valley's surface waters. Consequently, portions of the San Joaquin River contain elevated levels of Se and salts, which have exceeded levels considered safe for fish and wildlife species. In 1990 the EPA listed Carquinez Strait as an impaired waterbody due to elevated Se levels in diving ducks. In 1992 the EPA established aquatic life criteria for Se of 5 parts per billion (ppb) for the entire Bay-Delta Estuary (EPA National Toxics Rule, Code of Federal Regulations Part 131). The primary sources of Se in the San Joaquin River and Bay-Delta Estuary are subsurface agricultural discharge and treated wastewater discharges from oil refineries. Se is a by-product of the oil-refining process.

G1.1.1.3 Existing Drinking Water Resources

Project effects on drinking water quality derived from surface-water sources are heightened because approximately two-thirds of California's drinking water comes from the Delta region. Se, bromide, total organic carbon, and salts are constituents of major concern for drinking water, and salts are of importance to agricultural users of Delta water. In addition, high levels of TDS, salinity, and turbidity affect consumer acceptance of drinking water as well as treatment plant operations.

In 1995 the State Water Resources Control Board adopted the Water Quality Control Plan for the Bay-Delta Estuary. The main objectives of the plan are to adopt WQOs to protect the beneficial uses of water in the Bay-Delta Estuary against the adverse effects of water diversions and to implement these WQOs through water right orders. The State Water Resources Control Board encouraged interested parties to resolve among themselves the responsibilities for meeting the objective of the plan.

Water projects divert water from the Delta channels to meet the needs of approximately two-thirds of California's population. Central Valley Project water is delivered through the Contra Costa Canal to Contra Costa Water District (CCWD). The CCWD delivers water throughout eastern Contra Costa County providing for the municipal water needs of over 400,000 county residents. Water from the Delta is the primary source of water supply for 450,000 residents in central and eastern Contra Costa County. CCWD draws Delta water from Rock Slough, Old River near the town of Discovery Bay, and Mallard Slough. The water is transferred through the Contra Costa Canal to the CCWD's treatment plants and can also be stored in Los Vaqueros, Contra Loma, Mallard, and Martinez reservoirs. Los Vaqueros Reservoir becomes the major source during periods when use of Delta water is prohibited. Water taken from the reservoir is replaced at relatively high expense incurred by pumping costs.

Canal water is also delivered to industrial users, public water supply retailers, and to CCWD's treatment facilities (Bollman and Randall-Bold water treatment plants). Treated water is distributed to about 230,000 residents in Clayton, Clyde, Concord, Pacheco, Port Costa, and parts of Pleasant Hill, Martinez, and Walnut Creek. Some treated water is also distributed to Antioch, Bay Point, and Brentwood. CCWD also sells raw water to the cities of Antioch, Martinez, and Pittsburg, California Cities Water Company (Bay Point), and Diablo Water District (Oakley).

The raw-water quality varies considerably during the year and is a function of the sources of water in the canal. Tidal influences on water quality are especially important because they affect chloride and bromide ion concentrations in water delivered to the water treatment facilities. Total organic carbon concentration in Randall-Bold Water Treatment Plant raw water during November 2, 2000, through March 28, 2001, averaged 4.43 milligrams per liter (mg/L). The high was 5.06 mg/L on March 14, 2001, and the low was 2.45 mg/L on November 2, 2000. Bromide concentrations ranged from < 0.1 to 0.29 mg/L during that period and total dissolved solids (TDS) averaged 300 mg/L.

Algae occasionally pose problems at the treatment plant in that their populations vary seasonally in both type and number. A diatom, *Melosira*, has created problems in the past, most often reflected in short filter runs (6 to 8 hours). Randall-Bold Water Treatment Plant, being a direct filtration plant, is ill equipped by its design to effectively remove algae. Diatoms are particularly troublesome because they produce oils that make them float. In addition, many species resist coagulation and enmeshment in floc particles. As a result, large numbers are often present in filter-applied water. In some instances, diatoms (and other small algae) have been found in finished water. From 1997 through 1999, the average diatom count in raw water at the Randall-Bold Water Treatment Plant was 669 units/milliliter (mL). The counts were highly variable, however, as reflected by the median (85 units/mL) and standard deviations (2,592 units/mL). The maximum count over the period of record available for this report was 8,925 on February 22, 1999. Flagellated algae, which include many that produce grassy and fishy odors, have been observed in raw water at elevated population levels. In the period from 1997 through 1999, the data indicate an average of 100 units/mL (median 10 units/mL and standard deviation 411 units/mL). The count was 3,180 units/mL on March 1, 1999, the highest count during the period evaluated.

Blue-green algae (cyanobacteria) have appeared in raw water in small numbers but, apparently, have not caused shortened filter runs. Attached cyanobacterial growths in the canal, however, could result in troublesome earthy and musty odors, especially during the warmer months of the year. Flavor Profile Analysis data available for this report indicated a slight earthy odor only on a few occasions. Earthy and musty odors are commonly caused by nuisance cyanobacteria.

Table G1-1 below includes a summary of some raw water quality analytes from January 1998 to April 2000.

Table G1-1
Raw Drinking Water Quality Summary Table

Analyte	Average	Range
Turbidity (NTU)	4.5	0.83-12
Chloride (mg/L)	46.2	14 -120
Hardness (mg/L)	83.4	74-114
PH	8.0	7.6-9.1
Alkalinity (mg/L)	67.2	50-87
TDS (mg/L)	300	287 - 312
Bromide (mg/L)	0.2	< 0.1-0.27
Iron (µg/L)	297	< 100-430
Manganese (µg/L)	27	7.2-25.7

Note:
* Data are from January 1998-April 2000.

G1.1.1.4 Existing Bay-Delta Water Quality

Section 303(d) Listed Pollutants

CWA Section 303(d) requires each State to identify waters that will not achieve water quality standards after application of effluent limits. For each water and pollutant, the State is required to propose a priority for development of a load-based (as opposed to concentration-based) limit called the total maximum daily load (TMDL). The TMDL determines how much of a given pollutant can be discharged from a particular source without causing water quality standards to be violated. Priorities for development of TMDLs are set by the State based on the severity of the pollution and uses of the waters.

High-Priority Constituents. High priority constituents for TMDL implementation in the North and Central bays and the Delta include polychlorinated biphenyls (PCBs) and mercury. PCBs have been listed as high priority constituents by the EPA. Mercury is designated as high priority because consumption of fish and wildlife from San Francisco Bay is impacted, and a health advisory is in effect for multiple fish species, including striped bass and shark. In the Lower and South bays, high priority constituents include dioxin compounds, furan compounds, dioxin-like PCBs, and mercury.

Se is listed as a low-priority constituent in the Bay. It was given a low priority because individual control strategies have already been implemented at the refineries that discharge to the North Bay. The listing was developed due to elevated concentrations found in animal tissues in the Bay. Because of its bioaccumulatory character and the fact that it is a major component of Central Valley drainwater, Se is a highly important pollutant for the Bay-Delta in the context of this report. The introduction in the mid-1980s of exotic bivalve species may have made the food chain more susceptible to Se accumulation. Moreover, a human health advisory by the Regional Water Quality Control Board (Regional Board), San Francisco has been issued for the consumption of scaup and scoter (diving ducks) due to Se levels in these animals.

The potential discharge points for the extended San Luis Drain (the Drain) in the Delta are Chipps Island and Carquinez Strait. Due to the sites' proximity to local drinking water intakes, salinity is a high-priority constituent for these alternatives. Salinity is not an issue for discharge at Point Estero (potential ocean discharge) because the salinity of drainwater is less than that of this receiving water. In the San Joaquin River, high-priority constituents include Se, boron, electrical conductivity (salt), diazinon, and chlorpyrifos. TMDLs for the San Joaquin River are already in place for Se and have been proposed for salt and boron.

Medium-Priority Constituents. Constituents of medium-priority in the North Bay, Central Bay, and Delta include chlordane, dichlorodiphenyltrichloroethane (DDT), diazinon, and dieldrin. Diazinon and nondioxin-like PCBs are designated as medium-priority constituents in the Lower and South bays. The San Joaquin River Section 303(d) list includes mercury as a medium-priority constituent for TMDL implementation.

Copper is also a medium-priority constituent in several waters of the North Bay and Delta. Copper has been prioritized due to exceedances of EPA's California Toxics Rule (CTR) dissolved metals criteria, National Toxics Rule total metals criteria, elevated water and sediment concentrations, and elevated fish tissue levels. Specific waterbodies that have been listed include the Lower Bay, Central Bay, Carquinez Strait, San Pablo Bay, Suisun Bay, and the Delta. However, proposed amendments to the Section 303(d) list in 2001 have removed copper from the priority list due to recent toxicity studies that indicate copper is less toxic in the receiving waters than in the laboratory tests that formed the basis for the WQOs and criteria.

Low-Priority Constituents. In the North Bay and Delta, low-priority constituents on the Section 303(d) list are dioxins, furans, dioxin-like PCBs, and Se.

Pesticides, chlordane, DDT, and dieldrin have been designated by the EPA as low-priority constituents in the Lower and South bays.

DDT, Group A pesticides (aldrin, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane, endosulfan, and toxaphene), and Se are low-priority constituents in the San Joaquin River.

Se, as discussed above, is listed as a low-priority constituent in the Bay and Delta; however, because Se is a major constituent of Central Valley drainwater, it is a highly important constituent for the purposes of this report.

Salt TMDL. Salt concentrations in the San Joaquin River and Delta are a concern for many of the water users. The Regional Board, Central Valley has recently proposed a salt TMDL for the Lower San Joaquin River designed to reduce the loading of salt to the river (and subsequently reduce the concentrations in the river). No salt TMDL has been proposed for the Delta.

Water Quality Data Summary

The Regional Monitoring Program for Trace Substances (RMP) administered by San Francisco Estuary Institute (SFEI) for the Regional Board, San Francisco, and bay dischargers conducts monitoring three times a year along the main spine of the Bay, from the Delta to the South Bay (Figure G1-1). The RMP measures concentrations of trace constituents in water, sediment, and transplanted bivalves at various locations in the Bay-Delta Estuary. The monitoring station nearest the potential Carquinez Strait discharge location is Davis Point. The monitoring station nearest the potential Chipps Island discharge location is Honker Bay. Also shown are data for the San Joaquin and Sacramento River stations and the Golden Gate station, which have been included to estimate ambient concentrations at the potential ocean discharge point at the downstream edge of the Delta. RMP water data from 1993 to 2000 were summarized for pollutants of concern and are shown in Table G1-2.

The entire North Bay-Delta and the Golden Gate consistently exceed water quality criteria for PCBs. While the Sacramento and San Joaquin river stations contained the lowest PCB levels, the Golden Gate station showed the fewest criteria exceedances (Table G1-2). Polycyclic aromatic hydrocarbons (PAHs) were problematic in the North Bay as well. While the Golden Gate station and the Sacramento/San Joaquin river stations did not exceed PAH criteria during 1993-2000, all other North Bay-Delta stations did, although not to the same extent as for PCBs (Table G1-2).

At the Davis Point station no concentrations for pollutants of concern were significantly higher than the average for the entire North Bay-Delta. However, PAHs, PCBs, and total mercury exceeded water quality criteria at least once. Davis Point also contained the highest nickel and total Se concentrations in the North Bay-Delta but they never exceed water quality criteria. Davis Point's proximity to multiple industrial dischargers near Carquinez Strait may explain the station's higher concentrations.

The Honker Bay station, nearest to the potential Chipps Island discharge point, did not have available PAH or PCB data. Generally, Honker Bay concentrations for pollutants of concern were average for the North Bay and Delta.

Figure G1-1 Regional Monitoring Program Sampling Stations and Locations

Figure G1-1. Regional Monitoring Program Sampling Station Locations

Table G1-2
Summary of Regional Monitoring Program Data for San Francisco Bay-Delta

	Total PAHS (ng/L)	Total PCBs (pg/L)	Cu Dissolved (µg/L)	Ni Dissolved (µg/L)	Pb Dissolved (µg/L)	Se Dissolved (µg/L)	Se Total (µg/L)	Hg Total (µg/L)	Salinity (by SCT) o/oo
California Toxics Rule Water Quality Criteria (averaging period)			4.8 (1-hour)	74 (1-hour)	210 (1-hour)		20 (1-hour)		
		170 (30-day)	3.1 (4-day)	8.2 (4-day)	8.1 (4-day)		5 (4-day)	0.051 (30-day)	
Basin Plan Water Quality Objective (averaging period)	31 (30-day)							0.025 (4-day)	
Station									
Davis Point									
Mean	33.42	658.95	1.75	1.84	0.04	0.17	0.21	0.020	12.39
Median	25.00	413.50	1.80	1.68	0.01	0.17	0.18	0.013	11.20
Std Dev	23.97	538.64	0.39	0.70	0.10	0.07	0.09	0.020	7.88
# of Samples Exceeding Criteria	6/17	17/20	0/21	0/21	0/21		0/22	1/18	
Golden Gate									
Mean	5.68	311.26	0.47	0.63	0.01	0.18	0.17	0.0012	29.19
Median	5.00	126.00	0.40	0.60	0.01	0.12	0.12	0.0011	30.20
Std Dev	4.61	650.12	0.21	0.23	0.00	0.10	0.11	0.0005	3.79
# of Samples Exceeding Criteria	0/17	8/19	0/20	0/20	0/20		0/16	0/15	
Grizzly Bay									
Mean	29.38	521.95	1.89	1.52	0.08	0.16	0.17	0.023	2.89
Median	24.00	287.00	1.83	1.35	0.02	0.15	0.17	0.015	0.40
Std Dev	22.89	546.23	0.51	0.86	0.12	0.06	0.06	0.018	3.51
# of Samples Exceeding Criteria	6/16	17/19	0/21	0/21	0/21		0/22	1/19	
Honker Bay									
Mean	.	.	1.70	1.31	0.06	0.13	0.16	0.018	1.26
Median	.	.	1.65	1.15	0.05	0.12	0.15	0.014	0.00
Std Dev	.	.	0.41	0.44	0.06	0.05	0.05	0.013	1.95
# of Samples Exceeding Criteria	0/0	0/0	0/18	0/18	0/18		0/19	0/15	
Pacheco Creek									
Mean	.	.	1.84	1.55	0.07	0.18	0.19	0.015	4.03
Median	.	.	1.89	1.38	0.03	0.16	0.18	0.013	0.30
Std Dev	.	.	0.47	0.73	0.11	0.07	0.07	0.008	4.68
# of Samples Exceeding Criteria	0/0	0/0	0/21	0/21	0/21		0/21	0/18	
Point Pinole									
Mean	22.65	622.84	1.57	1.66	0.02	0.16	0.19	0.014	14.56
Median	18.50	323.00	1.50	1.46	0.01	0.15	0.17	0.009	15.85
Std Dev	16.54	792.29	0.27	0.56	0.02	0.07	0.08	0.012	7.31
# of Samples Exceeding Criteria	3/16	18/19	0/21	0/21	0/21		0/21	0/18	
Red Rock									
Mean	15.00	403.78	1.23	1.32	0.02	0.16	0.17	0.0055	20.45
Median	13.00	262.50	1.22	1.20	0.01	0.13	0.15	0.0047	21.20
Std Dev	10.73	513.11	0.41	0.45	0.02	0.10	0.08	0.0032	8.81
# of Samples Exceeding Criteria	1/17	16/18	0/18	0/18	0/18		0/16	0/16	
Sacramento River									
Mean	8.38	253.75	1.61	1.30	0.09	0.14	0.15	0.0086	0.17
Median	8.00	182.50	1.50	1.00	0.07	0.12	0.15	0.0060	0.00
Std Dev	3.95	201.85	0.42	0.64	0.08	0.07	0.06	0.0081	0.63
# of Samples Exceeding Criteria	0/17	11/20	0/21	0/21	0/21		0/20	0/19	
San Joaquin River									
Mean	7.88	209.56	1.82	1.27	0.10	0.17	0.18	0.0076	0.13
Median	6.10	172.50	1.70	1.10	0.07	0.16	0.18	0.0072	0.00
Std Dev	5.07	157.12	0.41	0.56	0.10	0.07	0.09	0.0037	0.40
# of Samples Exceeding Criteria	0/17	9/18	0/21	0/21	0/21		0/21	0/18	
San Pablo Bay									
Mean	40.79	742.95	1.65	1.73	0.04	0.16	0.19	0.024	13.73
Median	24.50	430.00	1.60	1.60	0.01	0.15	0.17	0.015	13.35
Std Dev	37.21	806.70	0.35	0.60	0.08	0.05	0.07	0.024	7.86
# of Samples Exceeding Criteria	7/16	19/20	0/21	0/21	0/21		0/21	2/18	
Listed Stations									
Average	20	469	1.56	1.42	0.05	0.16	0.18	0.014	9.86
Std Dev	22	592	0.56	0.67	0.08	0.07	0.08	0.015	10.73
Average Ocean Concentration (Bruland 1983)			0.266	0.491	0.00217	0.14		0.00105 (as dissolved)	35

Selenium in the North Bay-Delta

The processing of fossil fuels and irrigation of lands geologically derived from organic marine shales are two principal causes of Se mobilization in the environment. Both have caused significant Se loading to the northern Bay-Delta Estuary and Delta. Fossil fuel processing discharges at and near Carquinez Strait and the discharge of the San Joaquin River from the Central Valley, which contains Se-rich soil, have caused Se to be listed by the State as a key contaminant in the Bay-Delta. Se is known to be an efficient bioaccumulator, most often expressing toxicity in the form of reproductive defects and toxicity in higher fish and bird predators (Luoma and Presser 2000).

While Se levels found in water in the Bay-Delta are not significantly higher than those in other major estuaries (Cutter 1989), Se concentrations in bivalves have previously exceeded thresholds of toxicity for ingestion by predators (Luoma and Presser 2000). Also, concentrations in bivalve tissue and sediments have increased in the last few years (SFEI 2002), and perhaps the most important biological pathway for Se uptake is through benthic filter feeders (Luoma and Presser 2000).

The Delta receives water from the Sacramento and San Joaquin rivers; however, the Sacramento River does not contain appreciable amounts of Se. The San Joaquin River at Vernalis during the period from 1993 to 2000 contained average concentrations of total Se of 1.86 µg/L (Table G1-3). A higher percentage of freshwater flow from the Delta originates from the Sacramento River than the San Joaquin River. Average Se concentrations in the San Joaquin River as it exits the Delta (as measured by the RMP) are significantly lower than those measured at upstream locations such as near Vernalis or Crows Landing (Table G1-3).

Table G1-3
Summary of Regional Monitoring Program Results By Region

Constituent	RMP Stations			San Joaquin River at Vernalis[2]
	Golden Gate[1]	North Bay Avg[1]	San Joaquin (Delta)[1]	
Dissolved Copper (µg/L)[3]	0.47	1.66	1.82	
Dissolved Nickel (µg/L)[3]	0.63	1.56	1.27	
Dissolved Lead (µg/L)	0.01	0.05	0.1	
Dissolved Chromium (µg/L)	0.13	0.53	0.53	
Dissolved Cadmium (µg/L)	0.06	0.04	0.01	
Total Selenium (µg/L)[3]	0.17	0.18	0.18	1.86
Salinity (ppt)	29.19	9.9	0.01	0.35

Notes:
[1] Data from RMP, averages from 1993-2000 (SFEI 2002).
[2] Data from California Department of Water Resources, 1993-2000 (http://cdec.water.ca.gov).
[3] High-priority constituents.

G1.1.1.5 Regulatory Environment

Construction and operation of the alternatives under consideration would be subject to a variety of regulatory compliance actions that are in place to safeguard the human environment. Appendix F describes the major regulatory programs that pertain to the alternatives. The following sections describe the regulatory compliance requirements for surface-water resources in greater detail.

Water Quality Control Plans

Under the provisions of the Porter-Cologne Act and CWA, the Regional Boards implement water quality regulations in their respective watersheds. Each Regional Board adopts a Water Quality Control Plan (Basin Plan) describing the existing environment, WQOs, and implementation policies. The Basin Plan is updated every 5 years. The Basin Plan identifies beneficial uses and WQOs for waters of the State, including surface waters and groundwaters, as well as effluent limitations and discharge prohibitions intended to protect beneficial uses. A summary of regulatory provisions is contained in California Code of Regulations Title 23, Section 3912.

The Basin Plan identifies surface waters in each region as consisting of inland surface water (freshwater lakes, rivers, and streams), estuaries, enclosed bays, and ocean waters as applicable to the region. Historical and ongoing wasteloads contributed to the surface waterbodies in the region come from upstream discharges carried into the regions, direct input in the forms of point and nonpoint sources, and indirect input via groundwater seepage.

The Basin Plan describes the water quality control measures that contribute to the protection of the beneficial uses. The Basin Plan identifies beneficial uses for each segment of the Bay and its tributaries, WQOs for the reasonable protection of the uses, and an implementation plan for achieving these objectives. Beneficial uses for potentially affected surface waters are shown in Table G1-4.

Water Quality Objectives and Criteria

CWA Section 303 requires EPA to develop and adopt water quality criteria to protect beneficial uses of receiving waters. The Porter-Cologne Water Quality Control Act also contains similar requirements. Water quality objectives are promulgated and included in periodic updates to the Basin Plans. In California, EPA developed and adopted standards for certain toxic pollutants in the CTR as required under CWA Section 303 c (2) (B) (40 Code of Federal Regulations Part 131). Numeric water quality criteria contained in the CTR have not currently been incorporated into the Basin Plans.

Tables G1-5 and G1-6 show the lowest applicable water quality criteria for the Bay-Delta Disposal and Ocean Disposal locations.

Waste Discharge Permitting Program

Point source discharges to surface waters are generally controlled through Waste Discharge Requirements (WDRs) issued under Federal National Pollutant Discharge Elimination System (NPDES) permits. Although the NPDES program was established by the Federal CWA, the permits are prepared and enforced by the various Regional Boards, per California’s delegated authority for the act.

Table G1-4
Beneficial Uses of Potentially Affected Surface Waters

Basin	AGR	ASBS	COLD	COMM	EST	FRSH	GWR	IND	MAR	MIGR	MUN	NAV	PROC	RARE	REC-1	REC-2	SHELL	SPWN	WARM	WILD
Carquinez Strait and Suisun Bay				E	E			E		E		E		E	E	E		E		E
Bay-Delta Estuary	E	E	E	E	E		E	E		E	E	E	E	E	E	E	E	E	E	E
Ocean Waters		E						E	E	E		E		E	E	E		E		E
San Pablo Bay				E	E			E		E		E		E	E	E	E	E		E
South San Francisco Bay				E	E			E		E		E		E	E	E	E	P		E
Lower San Francisco Bay				E	E			E		E		E		E	E	E	E			E
Central San Francisco Bay				E	E			E		E		E	E	E	E	E	E	E		E

AGR – Agricultural supply
ASBS – Areas of special biological significance
COLD – Cold freshwater habitat
COMM – Ocean, commercial, and sport fishing
EST – Estuarine habitat
FRSH – Freshwater replenishment
GWR – Groundwater recharge
IND – Industrial service supply
MAR – Mariculture
MIGR – Fish migration
MUN – Municipal and domestic supply
NAV – Navigation
PROC – Industrial process supply
RARE – Preservation of rare and endangered species
REC1 – Contact water recreation
REC2 – Noncontact water recreation
SHELL – Shellfish harvesting
SPWN – Fish spawning
WARM – Warm freshwater habitat
WILD – Wildlife Habitat
E= Existing Use
P = Potential Use

Table G1-5
Selected Water Quality Objectives and Criteria for Ocean Waters

Constituent	Units	From California Ocean Plan: Limiting Concentrations: 6-month Median	Daily Maximum	Inst. Maximum	30-day Average
Ammonia	µg/L as N	600	2400	6000	
Antimony	µg/L				1200
Arsenic	µg/L	8	32	80	
Beryllium	µg/L				0.033
Cadmium	µg/L	1	4	10	
Chlorine, total resid	µg/L	2	8	60	
Chromium (hex. or total)	µg/L	2	8	20	
Chromium III	mg/l				190
Copper	µg/L	3	12	30	
Cyanide	µg/L	1	4	10	
Dissolved oxygen		Not to be depressed by more than 10% from natural levels			
Lead	µg/L	2	8	20	
Mercury	µg/L	0.04	0.16	0.4	
Nickel	µg/L	5	20	50	
pH	--	Less than 0.2-unit variation from natural level			
Selenium	µg/L	15	60	150	
Silver	µg/L	0.7	2.8	7	
Sulfide		In sediments, water near seds, no significant increase			
Thallium	µg/L				2
Tributyltin	µg/L				0.0014
Zinc	µg/L	20	80	200	
Acute toxicity	TUa	N/A	0.3	N/A	
Chronic toxicity	TUc	N/A	1	N/A	
Aldrin	µg/L				0.000022
Chlordane	µg/L				0.000023
DDT	µg/L				0.00017
Dieldrin	µg/L				0.00004
PCBs	µg/L				0.000019
Toxaphene	µg/L				0.00021

Notes:
1. Limits are from California Ocean Plan.
2. **Temperature requirements:** maximum discharge temperature will not exceed the natural receiving water temperature by more than 20°F; discharge will be far enough from an area of special biological significance (ASBS) to maintain natural temperature in the ASBS; discharge will not result in increases in the natural water temperature exceeding 4°F at the shoreline, at the surface of any ocean substrate, or at the ocean surface >1,000 feet from the discharge. Meeting the 20°F temperature difference between discharge and receiving water is anticipated to be sufficient to meet the other temperature requirements at the Point Estero discharge location; at Needle Point, a variance or exemption will be required for discharge to the ASBS.
3. **Water contact standards: total coliform** less than 1,000/100 mL, with no more than 20 percent of samples at any station, in any 30-day period, may exceed 1,000/100 mL; no single sample when verified within 48 hours will exceed 10,000/100 mL.
   Fecal coliform: based on 5 or more samples in any 30-day period, will not exceed geometric mean of 200/100 mL, nor will more than 10 percent of total samples during any 60-day period exceed 400/100 mL. Standards apply to water contact areas, including all kelp beds (outside of zone of initial dilution) and a zone within 1,000 feet of shore or the 30-foot depth contour, whichever is farthest from the shoreline. For shellfish harvesting areas, median coliform density will not exceed 70/100 mL, with no more than 10 percent of samples exceeding 230/100 mL.
4. Narrative **Toxicity** standard will apply.

Table G1-6
Selected Water Quality Objectives and Criteria for Bay-Delta Waters in the Carquinez Strait and Chipps Island Vicinity

Constituent	Units	Likely Receiving Water Objective/ Criteria	303d listing? (See Note 3)	Notes on Limits (see Note 4)	Source of Limit
Ammonia	mg/L	0.025		As annual median, with 0.16 maximum limit	Basin Plan limits as un-ionized ammonia
Antimony	µg/L	14		As long-term average concentration	CTR value for protection of human health (water + organisms)
Arsenic	µg/L	36		As 4-day average concentration	Basin Plan saltwater criterion (supersedes CTR value)
Cadmium	µg/L	1.1		As 4-day average concentration	Basin Plan criterion for freshwater, assuming hardness of 100 mg/L (supersedes CTR value), limit is for dissolved cadmium
Chromium 6 or total	µg/L	11		As 4-day average concentration	Basin Plan criterion for freshwater
Copper	µg/L	3.1	yes (2008)	As 1-hour or 1-day average concentration	CTR 4-day average criterion for saltwater, limit is for dissolved copper
Cyanide	µg/L	5		As 1-hour average	Basin Plan criterion for saltwater
Dissolved Oxygen	mg/L	7			Basin Plan criterion for tidal waters upstream of Carquinez Bridge
Lead	µg/L	3.2		As 4-day average concentration	Basin Plan criterion for freshwater, assuming 100 mg/L hardness (supersedes CTR value), limit is for dissolved lead
Mercury	µg/L	0.025	yes (2003)		Basin Plan criterion for freshwater and saltwater
Nickel	µg/L	7.10	yes (2010)	7.1 As 24-hr average; 8.3 As 4-day average	7.1 µg/L is Basin Plan criterion, 8.3 µg/L is EPA criterion (incorporated into Basin Plan)
pH	--	6.5-8.5		No change greater than 0.5 unit from ambient	Basin Plan objective
Selenium	µg/L	5	yes (2010)	As 4-day average concentration	CTR and National Toxics Rule for total recoverable selenium, applicable to waters of San Francisco Bay, Suisun Marsh, and Delta
Silver	µg/L	2.30		As instantaneous maximum	Basin Plan objective for dissolved silver in freshwater at hardness of 100 mg/L
Thallium	µg/L	1.7		As long-term average concentration	CTR value for protection of human health (water + organisms)
Zinc	µg/L	58.00		As 1-hour or 1-day average concentration	Basin Plan criterion for freshwater assuming 100 mg/L hardness (supersedes CTR)

Notes:
1. WQO and criteria are based upon the lowest of the CTR values and Basin Plan WQOs, including lowest of freshwater or saltwater limits.
2. For constituents that are currently on the Section 303(d) list (List of Impaired Waters), the TMDL process may determine ultimate mass loadings to the receiving water. The date of scheduled TMDL completion is shown.
3. Carquinez Strait and Suisun Bay are designation REC-1 and REC-2, with the following WQOs: **Fecal Coliform:** log mean <200 MPN/100 ml; 90th percentile <400 MPN/100 ml; **total coliform:** median < 240 MPN/100 ml with no sample > 10,000 MPN/100 ml, all based upon at least 5 consecutive samples equally spaced over 30-day period. EPA criteria also apply by use category, with the following numbers for steady-state and for maxima at designated beach, moderately used area, lightly used area, and infrequently used area: in colonies per 100 ml: **Enterococci** freshwater (33, 61, 89, 108, 151); **E. coli** freshwater (126, 235, 298, 406, 576); **Enterococci** saltwater (35, 104, 124, 276, 500). A dilution credit of 10:1 would likely be allowed for bacterial constituents.
4. Anticipated **temperature requirements:** discharge temperature will not exceed receiving water temperature by more than 20°F; discharge will not create a zone wherein the water temperature exceeds the receiving water temperature by more than 1°F over more than 25 percent of the cross-sectional channel area; discharge will not cause a surface-water temperature increase of more than 4°F above the natural receiving water temperature.
5. Narrative **Toxicity** Standard will apply.

Issued in 5-year terms, an NPDES permit usually contains components such as discharge prohibitions, effluent limitations, and necessary specifications and provisions to ensure proper treatment, storage, and disposal of the waste. The permit often contains a monitoring program that establishes monitoring stations at effluent outfall and receiving waters.

Under California's Porter-Cologne Water Quality Control Act, any person discharging or proposing to discharge waste within the region (except discharges into a community sewer system) that could affect the quality of the waters of the State is required to file a Report of Waste Discharge. The Regional Board reviews the nature of the proposed discharge and adopts WDRs to protect the beneficial uses of waters of the State. WDRs could be adopted for an individual discharge or for a specific type of discharge in the form of a general permit. The Regional Board may waive the requirements for filing a Report of Waste Discharge or issuing WDRs for a specific discharge where such a waiver is not against the public interest. NPDES requirements may not be waived.

Acceptable control measures for point source discharges must ensure compliance with NPDES permit conditions, including the discharge prohibitions and the effluent limitations provided by the Basin Plan. In addition, control measures must satisfy WQOs set forth in the Basin Plan, unless the Regional Board judges that related economic, environmental, or social considerations merit a modification after a public hearing process has been conducted. Control measures employed must be sufficiently flexible to accommodate future changes in technology, population growth, land development, and legal requirements.

Safe Drinking Water Act

This act (Public Law 99-339) became law in 1974 and was reauthorized in 1986 and again in August 1996. Through this act, the United States Congress gave the EPA the authority to set standards for contaminants in drinking water supplies. Amendments to this act provide more flexibility, more State responsibility, and more problem prevention approaches. The law changes the standard-setting procedure for drinking water and establishes a State Revolving Loan Fund to help public water systems improve their facilities, to ensure compliance with drinking water regulations, and to support State drinking water program activities.

Under provisions of this act, the California Department of Health and Safety (DHS) has the primary enforcement responsibility. The California Health and Safety Code establishes this authority and stipulates drinking water quality and monitoring standards. To maintain primacy, a State's drinking water regulations cannot be less stringent than the Federal standards.

The Underground Inspection Control Program, part of this act, provides the Federal authority for regulating deep-well injection. It establishes a scheme for the regulation of public drinking water systems and sets minimum standards for drinking water supplies. This program utilizes the complex operating, tracking, and monitoring requirements set up under the Federal hazardous waste statutes. Disposal of hazardous waste into an injection well generally requires compliance with both the Federal and State regulatory schemes: compliance with this program, including a Federal operating permit, a hazardous waste facilities permit from the DHS, and submission to the DHS and the Regional Board of a hydrological assessment report.

California Toxic Injection Well Control Act

The State has authority to regulate the deep-well injection of hazardous waste under the Toxic Injection Well Control Act and the Hazardous Waste Management Act. The Toxic Pits Control Act is inapplicable here as it only attempts to regulate surface impoundments. Both the Toxic Injection Well Control Act and Hazardous Waste Management Act recognize the increased occasion of contaminant migration from land treatment facilities, such as injection wells and, therefore, provide authority for State regulation.

G1.1.2 Environmental Consequences

G1.1.2.1 Key Impact and Evaluation Criteria

A series of modeling exercises were undertaken in this study to determine what effects may occur as a consequence of the alternatives at each of the out-of-valley discharge locations. The methodologies described in this section were developed to predict changes in salinity and Se concentrations both in the near-field and far-field. Near-field changes were considered significant if they resulted in obstruction of a critical zone of passage for sensitive species. Far-field changes in TDS concentrations were predicted at major CCWD intake locations in the Delta and intakes located near Antioch in the Bay and compared to existing conditions. Increases over existing conditions were deemed significant if they would result in the CCWD being unable to use the intake. Predicted changes in Se concentrations were compared to Federal and State WQOs, and were used to estimate changes in bioaccumulation. Toxic effects levels due to bioaccumulation were derived from a review of the scientific literature.

G1.1.2.2 Modeling Method and Assumptions

A variety of modeling tools were used to assist in the evaluation of potential impacts of disposal to the Bay-Delta and ocean. Near-field changes (adjacent to the discharge) were assessed using EPA's Visual Plumes modeling software to determine the size of the mixing zone (where discharge water is initially diluted with receiving water). Far-field changes (away from the mixing zone) were assessed using one-dimensional and two-dimensional hydrodynamic water quality models. Changes in Se concentrations were predicted using the two-dimensional hydrodynamic and water quality model coupled with a bioaccumulation model. Each of these models is described below.

Near-Field Modeling Method and Assumptions

In general, the Se and TDS concentrations resulting from the potential discharges are the key water quality concerns. However, for the localized diffuser analysis only, Se concentrations were modeled for several reasons. In the case of the Ocean Disposal Alternative, TDS concentration is irrelevant since the receiving ocean water is far more saline than the effluent. In the case of the Delta Disposal Alternatives, TDS is primarily a human health drinking water concern. Therefore, the TDS impact at more distant Delta drinking water intakes is more important than the TDS impact on aquatic biota directly adjacent to the diffusers, as evidenced by the existence of EPA and DHS water quality guidance on TDS concentrations with respect to human health and the lack of TDS water quality standards for aquatic life. Therefore, Se concentration was the focus of this analysis, and the TDS diffuser plume was neglected. The aquatic life criterion of 5 ppb of Se reported in the CTR was used as the standard for evaluating the diffuser design and resultant plume for the Delta Alternatives, while the Ocean Plan criteria of 15 ppb was used for the Point Estero evaluation. Table G1-7 summarizes effluent data that formed the basis of the diffuser designs and analysis.

Table G1-7
Key Effluent Diffuser Design and Analysis Data

Effluent Characteristic	Value
Flow Rate	41 cfs
TDS/Salinity Concentration*	17 ppt
Temperature	50.7°F = 10.4°C (Winter) 79.4°F = 26.3°C (Summer)
Se Concentration	360 ppb for Ocean and 72 ppb for Delta

Note:
* For the purposes of this analysis, the design TDS concentration of 17,000 ppm (17 ppt) was assumed to be equivalent to the effluent salinity. Although this correlation is not perfect, the assumption is reasonable given the preliminary nature of this analysis.

Delta Discharge Locations: Carquinez Strait and Chipps Island. In combination with the effluent data provided in Table G1-7, ambient temperature and salinity data for Carquinez Strait near Martinez, reported by Brown and Caldwell (1987), were used to formulate a preliminary diffuser design for the two Delta disposal sites. Temperature and salinity data for both summer and winter conditions were simulated since seasonal fluctuations can significantly alter the characteristics of the diffuser plume. As before, worst-case zero velocity scenarios were simulated, along with 0.91 meter/second (3.0 feet/second) current velocity scenarios. Table G1-8 summarizes the ambient temperature and salinity data used in this analysis.

Table G1-8
Ambient Temperature and Salinity Data, Carquinez Strait, California

Summer Conditions			Winter Conditions		
Depth (meters)	Salinity (ppt)	Temperature (°C)	Depth (meters)	Salinity (ppt)	Temperature (°C)
0.00	19.56	14.78	0.00	17.50	8.00
0.50	19.59	14.79	1.52	17.50	8.00
2.13	20.63	14.82	2.13	17.30	7.67
3.96	20.62	14.88	2.74	17.93	6.67
6.20	20.68	14.82	3.35	17.23	6.21
			3.96	17.26	6.21
			4.57	17.39	6.22
			5.18	17.52	6.26
			5.79	17.34	6.96
			6.10	17.34	6.96

Source: Brown and Caldwell 1987.

Based on these data, EPA's Visual Plumes program was used to design a diffuser to meet the CTR Se concentration criterion of 5 ppb within a reasonable zone of initial dilution. The depth of the water column was assumed to be 6.2 meters, although depths at both Carquinez Strait and Chipps Island fluctuate daily due to tidal influence. According to U.S. Geological Survey (USGS) topographic surveys, a 6.2-meter depth represents a very low-tide condition since depths generally exceed 9 meters at mean low tide in both locations. Tideflex® diffuser valves were specified for all diffuser ports to maintain adequate diffuser velocity and prevent debris accumulation within the diffuser. Two diffuser alternatives were developed for the Delta sites. The first alternative is an approximately 59-meter-long diffuser with 40 ports spaced every 1.5 meters, which should be viewed as the minimum diffuser length that would still achieve the water quality criterion. The second alternative is an approximately 200-meter-long diffuser that stretches across two-thirds of the channel, with 70 ports spaced every 7.25 meters. This more conservative alternative would achieve complete mixing across the channel width more quickly than the first. If it is economically feasible and allowed, the second alternative should be preferred over the first. Key diffuser design parameters for both alternatives are listed in Table G1-9.

Table G1-9
Diffuser Design Parameters, Bay-Delta Discharge Locations

Diffuser Design Parameter	Alternative 1	Alternative 2
Diffuser port valve type	Tideflex®	Tideflex®
Port diameter	10 centimeters	7.6 centimeters
Diffuser depth	6.2 meters	6.2 meters
Port elevation above channel bottom	0.61 meter	0.61 meter
Port angle	45° from vertical	45° from vertical
Number of ports	40	70
Port spacing	1.5 meters on center	7.25 meters on center
Diffuser length	59 meters	200 meters
Diffuser discharge velocity	3.58 meters/second (11.8 fps)	3.64 meters/second (11.9 fps)

Source: Flow Science Visual Plumes analysis, 2002.

Ocean Discharge Location: Point Estero. In combination with the effluent data in Table G1-7, ambient ocean data gathered from several sources were used to formulate a preliminary diffuser design for the Point Estero ocean disposal site. Data sources included the California Cooperative Oceanic Fisheries Investigations program, Coastal Data Information Program of the Scripps Institution of Oceanography at UC San Diego, National Oceanic and Atmospheric Administration's National Data Buoy Center, and Central California Coastal Circulation Study. Data were gathered from both web sites and published reports. Both summer and winter ambient conditions were simulated since seasonal fluctuations can significantly alter the characteristics of the diffuser plume. A worst-case current velocity scenario where no ocean current is present to disperse the effluent was also simulated. Table G1-10 summarizes the ambient ocean data used in this analysis.

Table G1-10
Ambient Ocean Data, Point Estero, California

Depth (meters)	Salinity, Summer and Winter (ppt)	Temperature (°C)		Ocean Currents				
		Summer	Winter	Worst-Case Velocity (m/s)	Maximum Speed, Summer (m/s)	Dominant Direction, Summer (°)	Maximum Speed, Winter (m/s)	Dominant Direction, Winter (°)
0	33.4	16.8	11.3					
10				0.0			0.447	75
20	33.4	15.0	11.3					
25				0.0	0.470	95	0.678	275
41				0.0	0.506	95	0.683	285
50	33.5	11.8	10.2					
57				0.0	0.576	95	0.629	285
73				0.0	0.485	95	0.588	105
75	33.6	10.3	9.6					
89				0.0	0.514	95	0.545	95
100	33.7	9.5	9.0					
105				0.0	0.440	105	0.486	95

Sources: California Cooperative Oceanic Fisheries Investigations Program, Coastal Data Information Program, National Data Buoy Center, and Central California Coastal Circulation Study data collected by Flow Science, 2002.

Based on these data, EPA's Visual Plumes program was used to design a diffuser to meet the California Ocean Plan Se concentration criterion of 15 ppb within a reasonable zone of initial dilution (Table G1-11). A diffuser depth of 60 meters was modeled using Visual Plumes. For this diffuser design, under worst-case ocean current conditions (i.e., zero velocity), the resulting Se plume would reach a concentration of 15 ppb at a minimum depth of approximately 48 meters under winter temperature conditions. For this scenario, the plume would be a maximum of approximately 3.1 meters wide and 87 meters long. Under maximum ocean current conditions (both summer and winter), the 15 ppb criterion would be achieved approximately 1 meter above the diffuser ports. The plume would be approximately 1 meter wide and 85 meters long at that point.

Table G1-11
Diffuser Design Parameters, Point Estero Diffuser

Diffuser Design Parameter	Value
Diffuser port valve type	Tideflex®
Port diameter	7.5 cm
Diffuser Depth	60 m
Port elevation above ocean floor	0.61 m
Port angle	Vertical (0°)
Number of ports	70
Port spacing	1.2 meters on center
Diffuser length	84 meters
Diffuser discharge velocity	3.64 meters/second (11.9 feet/second)

Source: Flow Science Visual Plumes analysis, 2002.

Far-Field Modeling Method and Assumptions

Modeling was the primary tool used to assess far-field changes due to the Chipps Island and Carquinez Strait discharges. The one-dimensional Fischer-Delta Model (FDM) Version 8.2 was used to predict changes in salinity concentrations in the Delta and in the Bay to Carquinez Strait. The two-dimensional MIKE 21 model was used to predict changes in salinity and Se concentrations in the Bay and in the Delta to Jersey Island.

Fischer Delta Model

To provide a realistic simulation of the likely impact of the potential Chipps Island discharge, a 35-year simulation was prepared using the actual Delta flows, exports, and hydrology for the period 1956–1991. For these simulations FDM Version 8.2 was used with San Francisco Bay replaced by a downstream boundary condition at Carquinez Strait. This model has been widely used to simulate the operation of the Delta, and the State Water Resources Control Board has accepted the model output in several permit hearings. The modeled grid is shown on Figure G1-2.

The discharge at Chipps Island is presumed to have a flow rate of 41 cfs with a total dissolved salt concentration of 17,000 ppm, representing a discharge of 19.7 kilograms per second of salt. The 41 cfs discharge represents average annual flow conditions. Since the seasonal peak in flow rate will be regulated by the storage capacity of the aquifer beneath the potential San Luis Drain reuse facilities, a constant flow is expected over the course of the year. The Se concentration in the discharge is assumed to be 72 μg/L (or ppb).

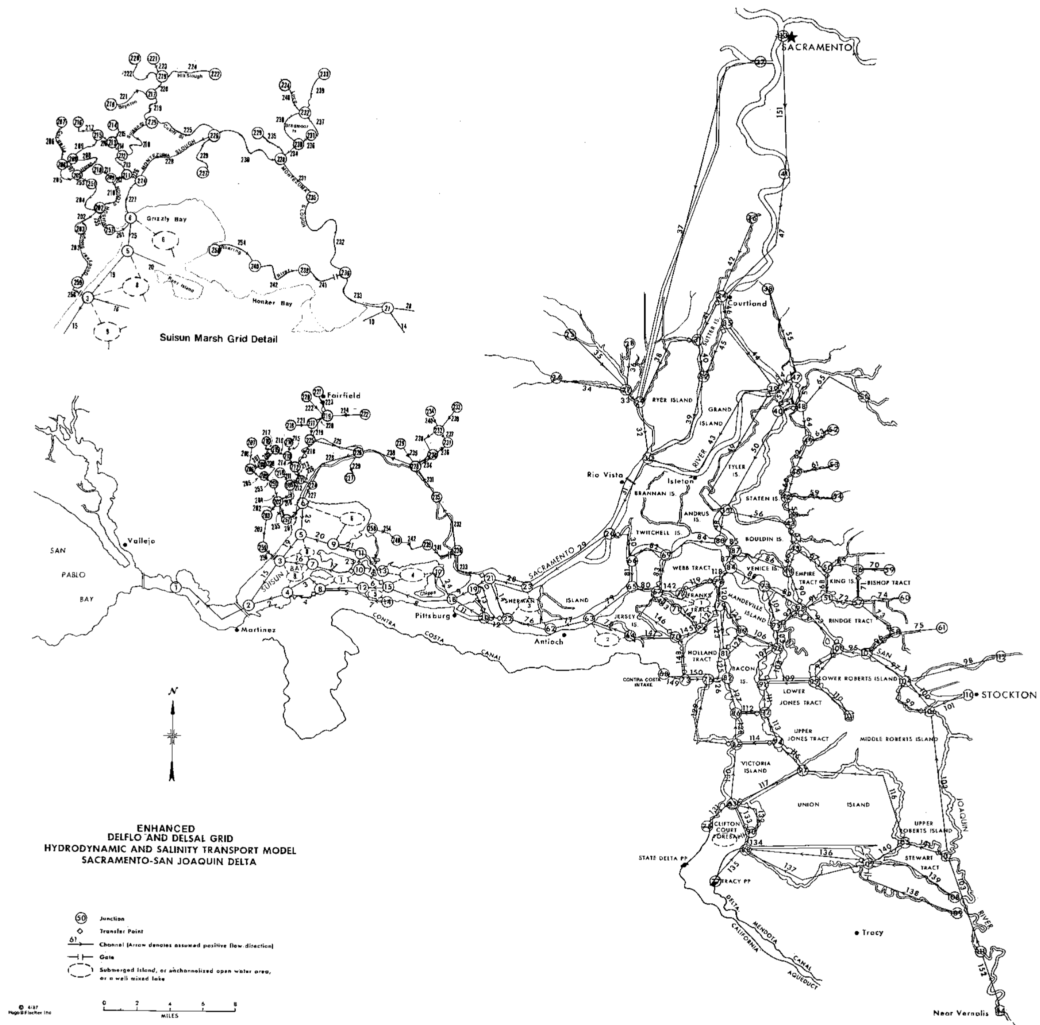
The addition of 41 cfs of flow to the Delta at Chipps Island provides a negligible increase in the total estuary flow at that location so that the actual drainage flow rate is insignificant in relation to natural Delta flows. The modeling assumes that the discharge will be uniformly mixed across the river by a multiport diffuser, enabling a far-field analysis to be carried out on the basis that the discharge is completely mixed with the river at the point of discharge.

MIKE 21 Salinity and Selenium Model

The effect of the San Luis Drain discharge at Chipps Island and Carquinez Strait on TDS and Se concentrations in San Francisco Bay and the Delta was modeled in this study using the MIKE 21 software developed by the Danish Hydraulic Institute (DHI 1998a, b). MIKE 21 is a two-dimensional, finite difference, free surface modeling system that has been used to simulate hydraulics and hydraulics-related phenomena in estuaries, coastal waters, and seas where stratification can be neglected.

MIKE 21 consists of three linked modules. The first is a hydrodynamic module (MIKE 21 HD) that solves the time-dependent, vertically integrated equations of continuity and conservation of momentum in two horizontal directions. The second is an advection-dispersion module (MIKE 21 AD) that calculates the transport of conservative substances such as TDS in the water column. Lastly, the heavy metals module (MIKE 21 ME) uses the computational algorithms from MIKE 21 HD and AD, but additionally calculates nonconservative mass transfer (i.e., sorption) between dissolved Se and suspended or benthic sediment.

The first step in using this MIKE 21 modeling software was to properly define the system to be modeled, identify the important processes to be included, and calibrate the model. In this study, the model domain was the Bay-Delta Estuary from Jersey Island in the Delta to the Pacific



URS	17324004	Fischer-Delta Model Grid	FIGURE G1-2
	San Luis Drainage Feature Re-evaluation		

Ocean, discretized into 200- by 200-meter rectangular grid cells (Figure G1-3). The processes included in the model were tides, wind, waves, erosion, deposition, diffusion, adsorption, and desorption. In addition, loading from major watersheds draining to the Bay was important for sediment, salt, and Se. Model calibration is further discussed in Attachment G1.1.

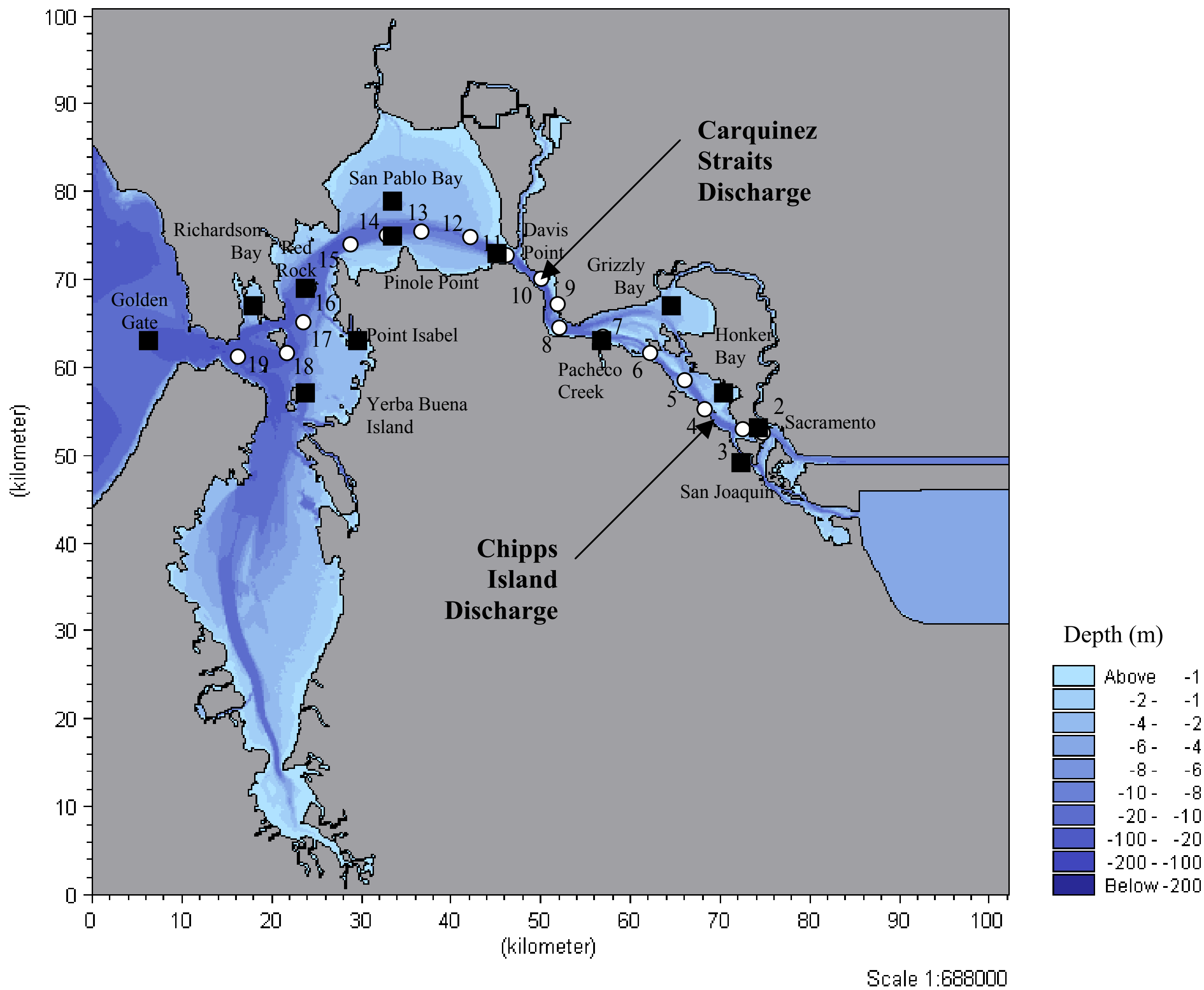
Due to the large computational time required to solve two-dimensional equations, a 12-month simulation period was selected for modeling. The first 6 months were used for spin-up, as initial model simulations indicated steady-state concentrations relative to the discharge were achieved after 3 to 6 months. To ensure that predictions are conservative, a 6-month period during the 1977 Dry Season was analyzed for TDS. The Delta flows from this period represent the lowest on record, thereby allowing the greatest transport of discharged components upstream. For Se, the model was calibrated to Water Year 1997 because water quality data for 1977 are limited. Changes in dissolved, adsorbed, and benthic Se concentrations were subsequently assessed relative to a hypothetical Dry Season using hydrodynamic flows from 1997, but current refinery Se loads.

The locations of the Chipps Island and Carquinez Strait discharges are displayed on Figure G1-3. The flowrate and concentrations of salt and Se used in the model simulations were 41 cfs flowrate, 17,000 ppm salt, and 72 ppb Se. Results were analyzed temporally at six locations in the North and Central bays, including the Martinez and Suisun Bay stations analyzed by the FDM. Results are reported as time series and probabilities of exceeding given concentrations. Average concentrations for the North Bay and Delta are also presented.

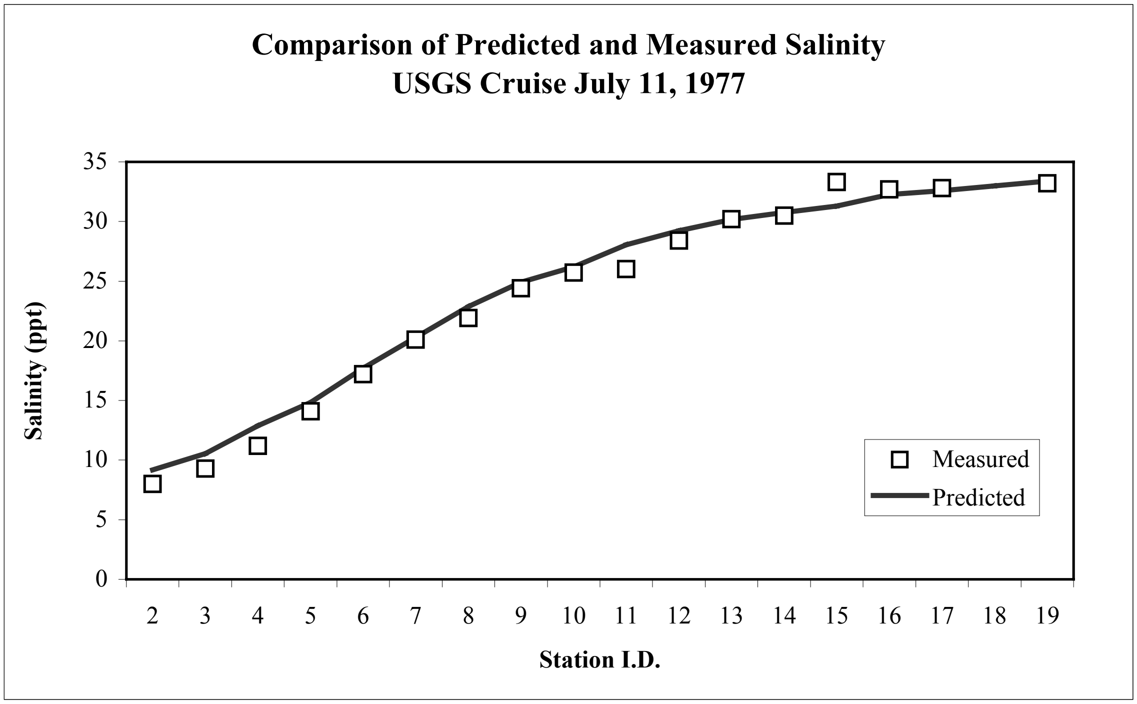
The first limitation of the MIKE 21 model is that only one grain-size fraction (i.e., mud) can be modeled. Because Se concentrations of sand are less than mud, this leads to overestimated Se concentrations in areas where sand is a significant fraction of the total benthic or suspended sediment concentration (e.g., the Central Bay). The second limitation is that only one partition coefficient is used to describe the interaction between dissolved and adsorbed Se, despite the fact that multiple forms of dissolved Se and multiple types of particles can act as sorptive surfaces. This leads to model predictions that better replicate average rather than instantaneous concentrations.

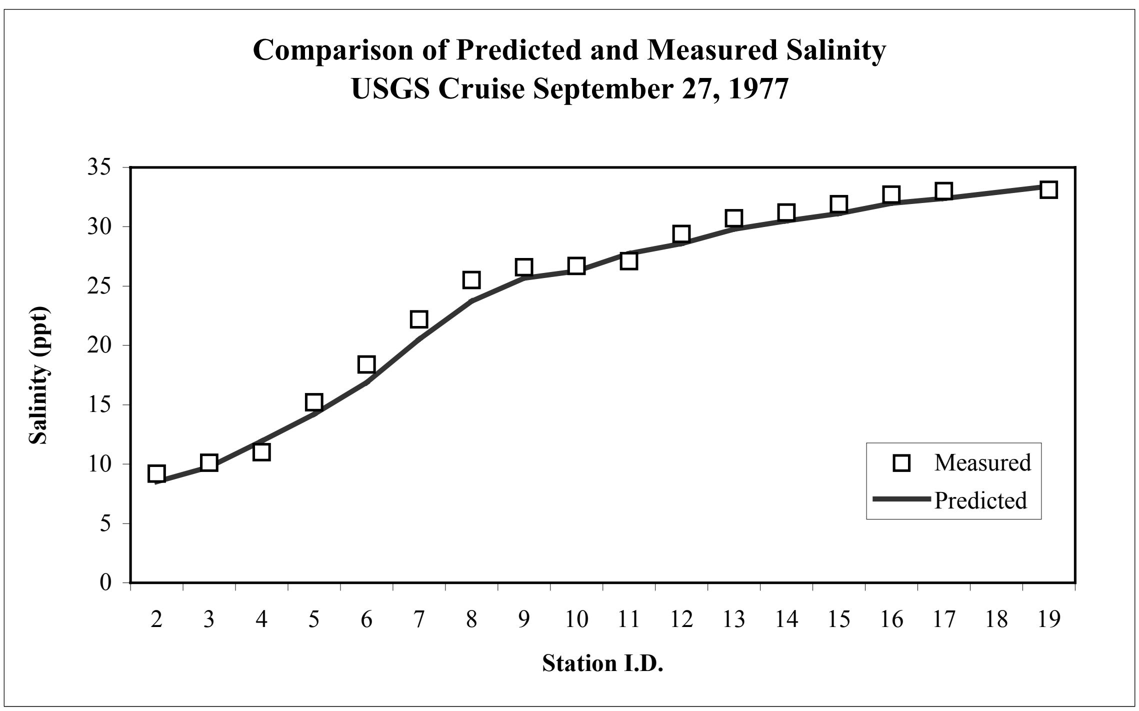
MIKE 21 Model Calibration. An overview of model calibration results are presented for TDS and Se. It should be noted this model has been extensively calibrated and validated as a part of recent planning for the San Francisco International Airport Runway Reconfiguration Project EIS/EIR conducted by URS for the Federal Aviation Administration and the City of San Francisco Office of Environmental Review. The model calibration and validation was also reviewed by a national panel convened by the National Oceanic and Atmospheric Administration.

TDS Concentrations. Measured and predicted TDS at the 18 USGS monitoring stations displayed on Figure G1-3 are shown on Figures G1-4a and G1-4b for four 1977 cruises. TDS is well calibrated by the model, and no consistent bias occurs at any station. Concentrations near the Golden Gate are relatively constant during this period, whereas concentrations at the easternmost station varies between 5,000 and 10,000 ppm, most likely reflecting the time within the tide cycle that measurements were taken. A 6-month mean TDS concentration for the simulation period is shown on Figure G1-4c. TDS decreases from a relatively constant value of 33,000 ppm at the Pacific Ocean boundary to less than 4,000 ppm near the Sacramento and San

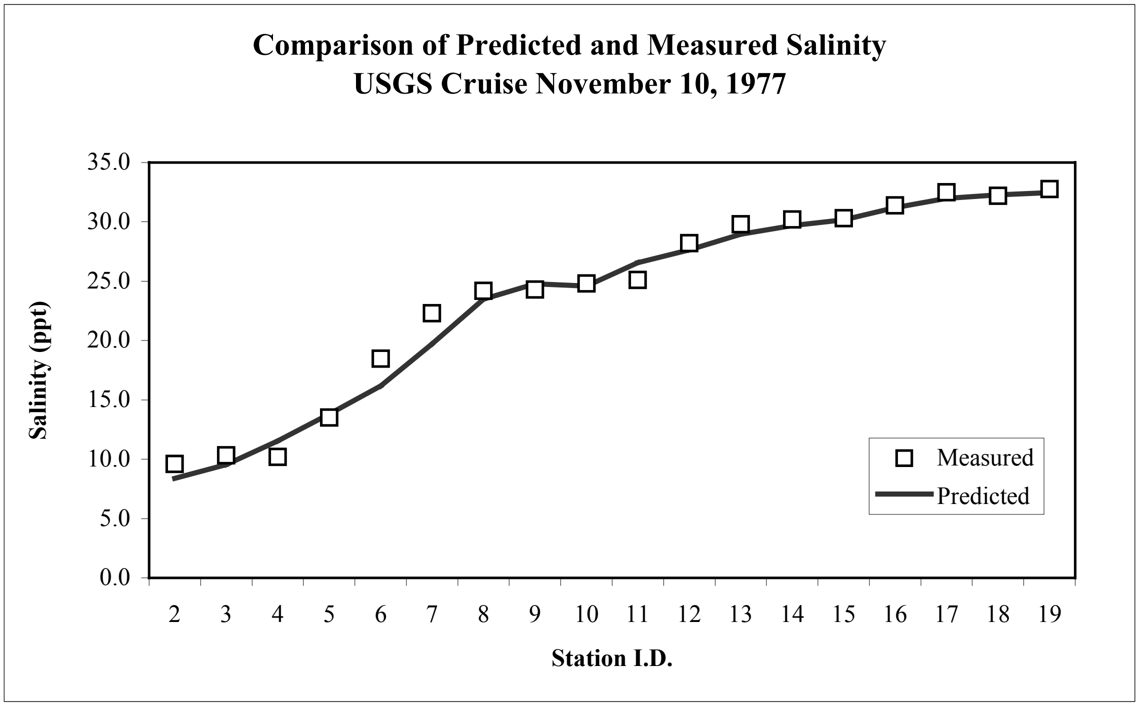


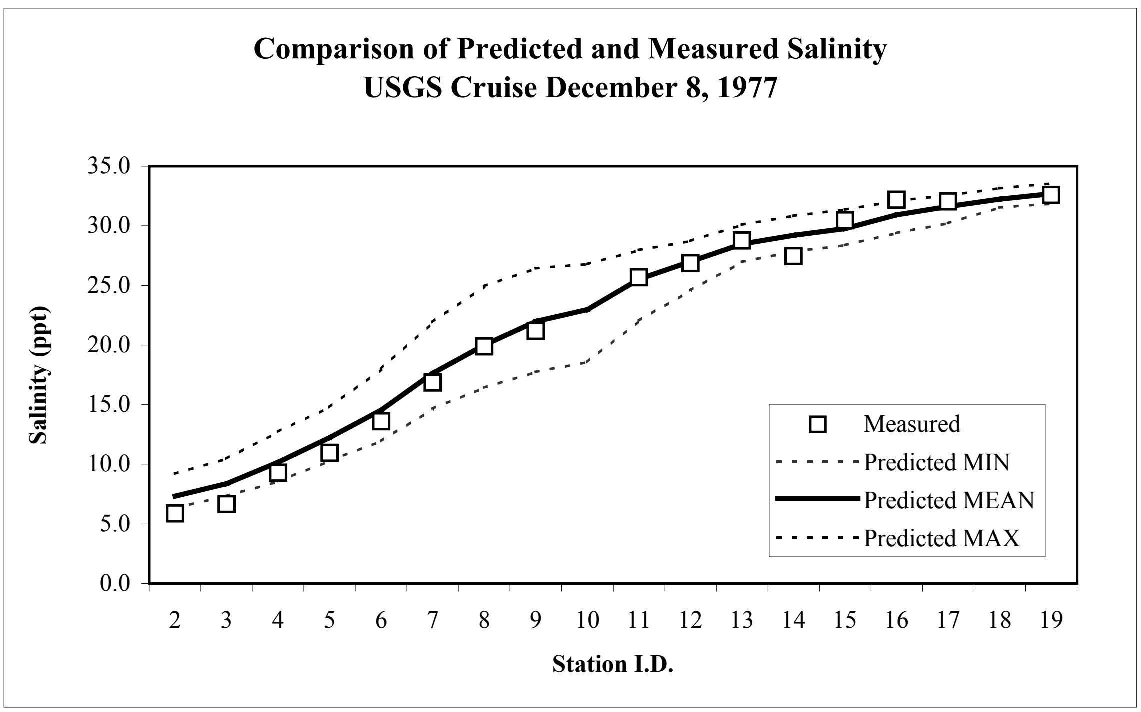
URS	17324004 San Luis Drainage Feature Re-evaluation	Bathymetry for MIKE 21 Model and Location of Modeled Discharges and USGS (Open Circles) and RMP (Closed Squares) Monitoring Stations	FIGURE G1-3



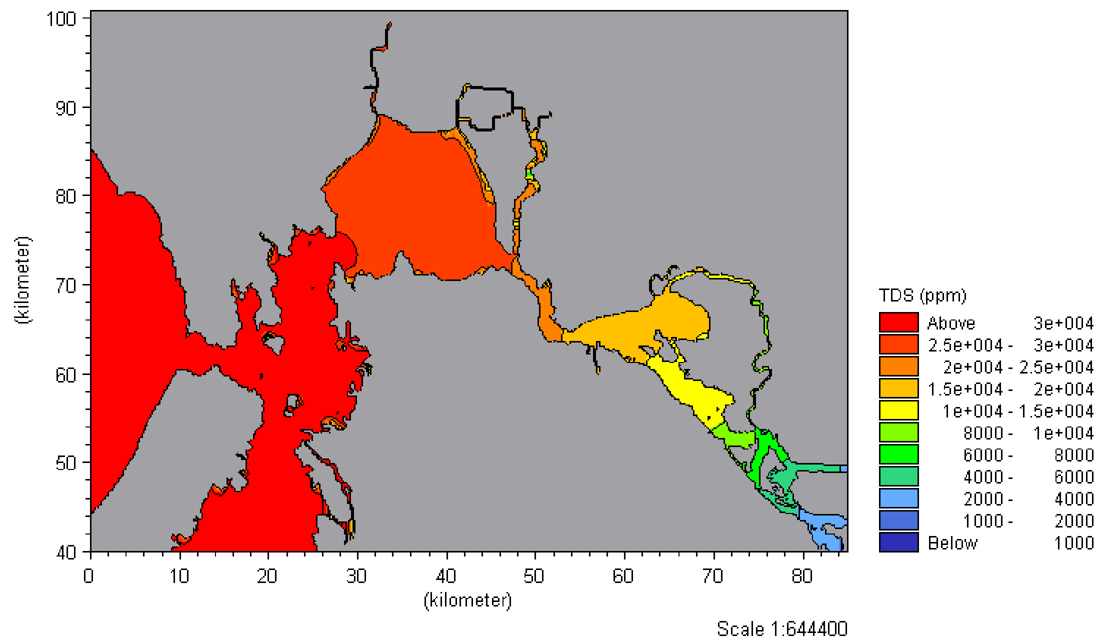


URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 North and Central Bay Salinity Calibration Results For Water Year 1977 (July and September Cruises)	FIGURE G1-4a





URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 North and Central Bay Salinity Calibration Results For Water Year 1977 (November and December Cruises)	FIGURE G1-4b



URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Predicted Existing Conditions Mean Total Dissolved Solids Concentration (July-December 1977)	FIGURE G1-4c

Joaquin rivers. Mean concentrations at the Chipps Island and Carquinez Strait discharge locations are 10,000 and 24,000 ppm, respectively.

Selenium Concentrations. Measured and predicted dissolved Se concentrations at the 12 RMP monitoring stations displayed on Figure G1-3 are shown as time series on Figures G1-5a and G1-5b for the calibration year 1997. Maximum dissolved Se concentrations occur between January and March, with the highest concentrations found at the San Joaquin River station.

A 6-month mean dissolved Se concentration for the 1997 base case is shown on the lower plot on Figure G1-5c. Dissolved concentrations vary between 0.05 and 0.2 µg/L, with the highest concentrations near the San Joaquin River and the lowest concentrations near the Pacific Ocean and the mouth of several tributaries (including the Sacramento River). Concentrations of total (dissolved plus adsorbed) Se are shown on the upper plot of Figure G1-5c to be below the Chronic Water Quality Objective of 5 µg/L throughout the Bay. Maximum concentrations of total Se are between 0.25 and 0.30 µg/L, and occur near the San Joaquin River and in San Pablo Bay. These concentrations are influenced by the higher amount of suspended sediment (and consequently adsorbed Se) as shown on the upper plot on Figure G1-5d. Finally, as illustrated on the lower plot on Figure G1-5d, the highest benthic Se concentrations are generally predicted in the Central Bay (a consequence of only modeling mud as discussed above).

G1.1.2.3 No Action Alternative

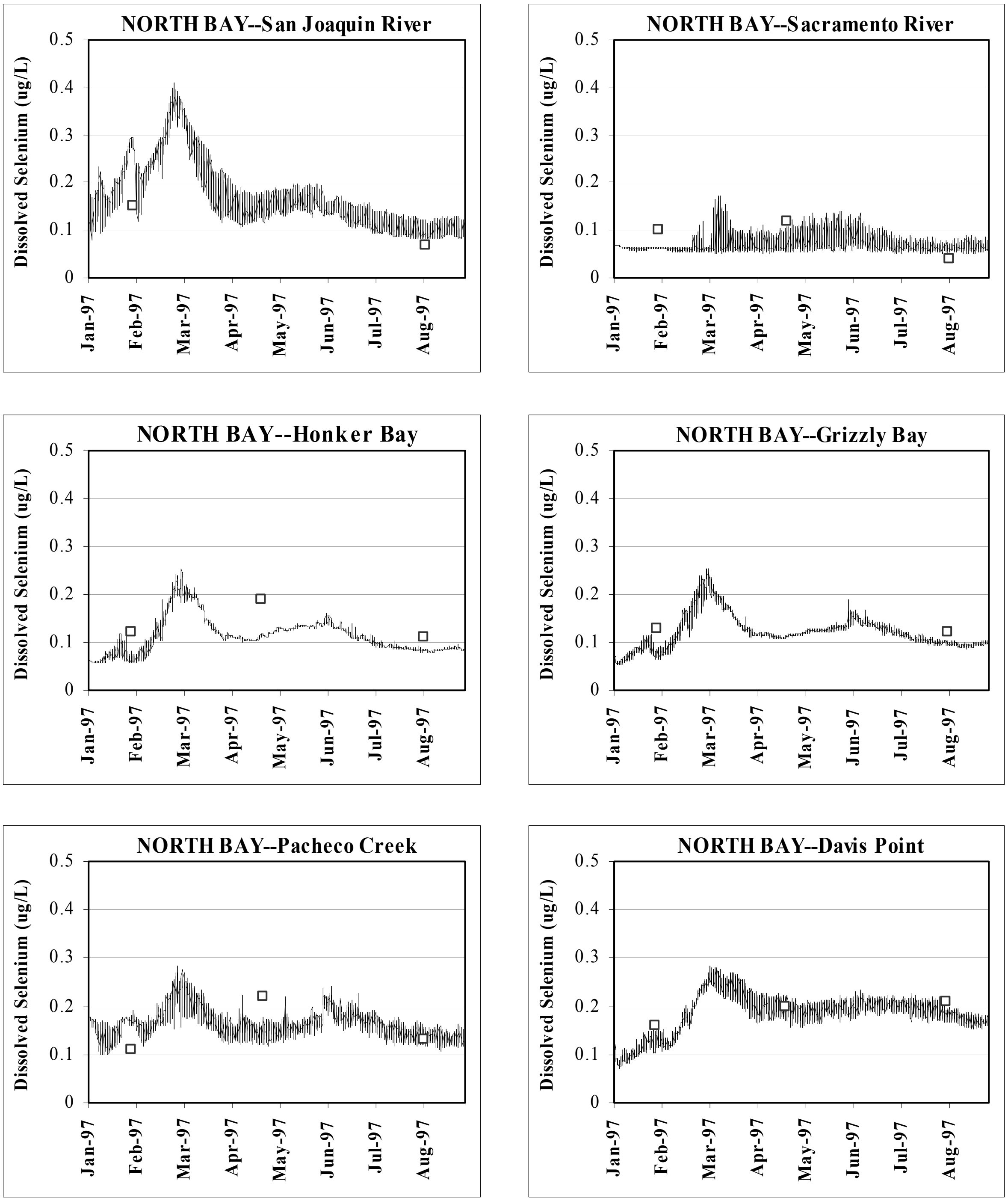
The No Action Alternative evaluates the effect of not conveying drainwater out of the study area for disposal. This alternative is defined as what could be expected to occur in the foreseeable future (2002 through 2050) if drainage service is not provided to the San Luis Unit (the Unit) and related areas. It represents existing conditions for drainage management plus changes in management reasonably expected to be implemented by individual farmers and districts in the absence of Federal drainage services and not of a magnitude to require CEQA/NEPA documentation (e.g., not new projects). The No Action Alternative includes only regional conveyance, treatment, or disposal facilities that existed in 2001, or that are authorized, funded projects.

Construction Impacts

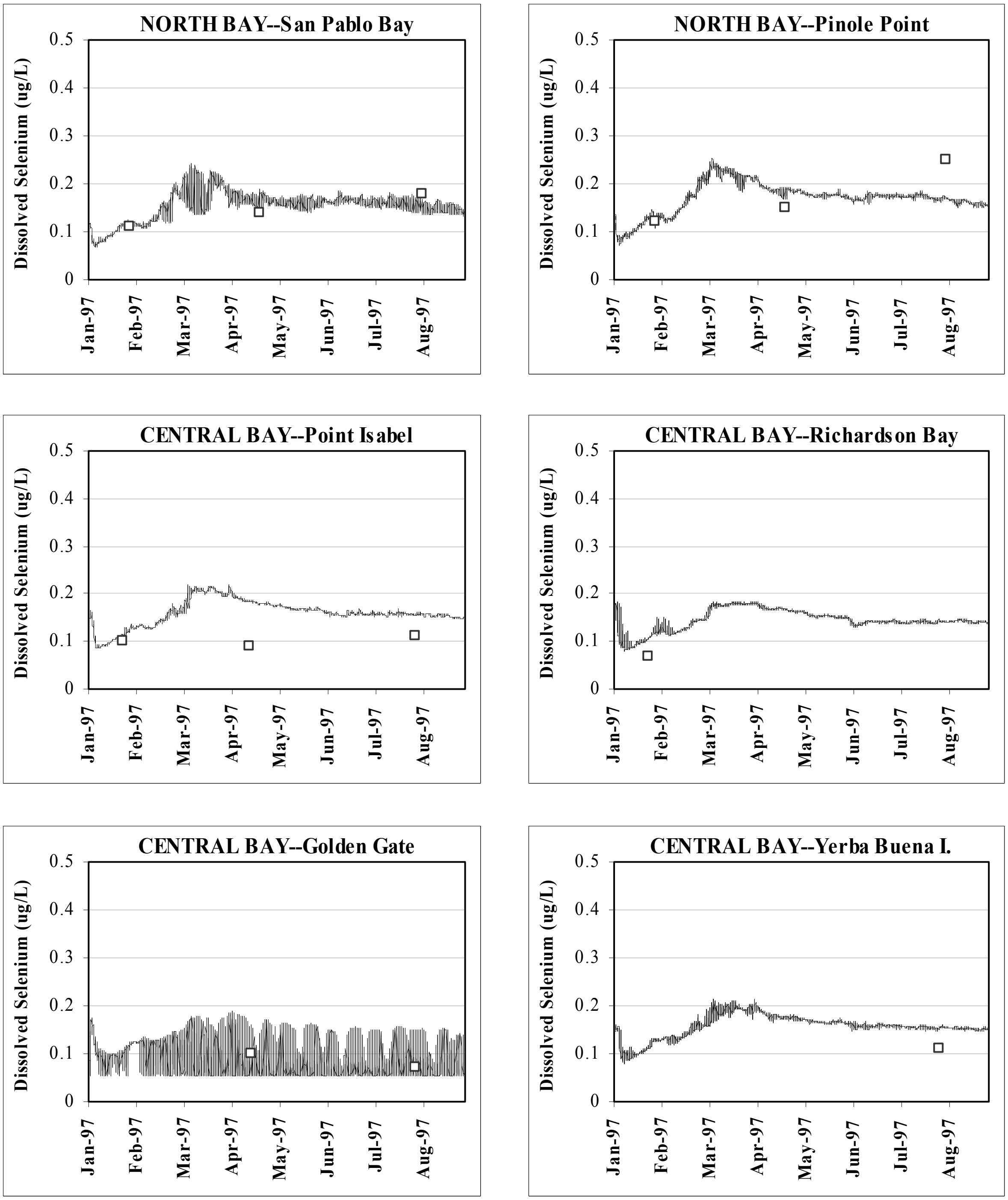
No new Federal construction will occur as part of the No Action Alternative. Therefore, no construction impacts are predicted.

Operational Impacts

It is not anticipated that any new water quality impacts would occur except for impacts on groundwater quality that could result in increased salinity and Se in the San Joaquin River due to seepage discharges. Implementation of new and evolving water quality control programs such as TMDLs should result in a gradual improvement in surface-water quality in the San Joaquin River, Delta, and Bay. However, increased water demand and competition for scarce water supplies in the absence of new storage may result in unknown and potentially adverse impacts.



	17324004	MIKE 21 North Bay Dissolved Selenium Calibration Results For Water Year 1997 (January through August RMP Cruises)	FIGURE G1-5a
	San Luis Drainage Feature Re-evaluation		



URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 San Pablo Bay and Central Bay Dissolved Selenium Calibration Results For Water Year 1997 (January through August RMP Cruises)	FIGURE G1-5b

G1.1.2.4 Ocean Disposal Alternative

This alternative collects drainwater along the existing San Luis Drain and through a series of pumping stations, piping, tunneling, and a 1-mile-long siphon and discharges the drainwater about 10 miles north of the city of San Luis Obispo, CA, into the ocean near Point Estero. Approximately 175 miles of pipeline would be installed plus 2 miles of tunnel and approximately 1.5 miles of marine pipeline. The outfall location is approximately 10 miles south of Monterey Bay National Marine Sanctuary and 200 feet below sea level 1.44 miles off shore from Point Estero.

Construction Impacts

The construction impacts would be concentrated in southern San Joaquin Valley. The Ocean Disposal Alternative results in the installation of the most miles of pipeline, canal, and 10 pumping stations. Construction impacts are mainly limited to soil erosion and resultant turbidity of surface streams. No impacts would occur to groundwater during construction.

Operational Impacts

The aqueduct, which is a combination of pipeline, tunnels, and pumping plants, traverses through and over the Coast Ranges and then discharges the drainwater into the ocean. The concentrated drainwater would have increased levels of salt and Se, but because of the closed nature of the aqueduct little chance exists of spills or seepage of drainwater to the groundwater or surface water along the route.

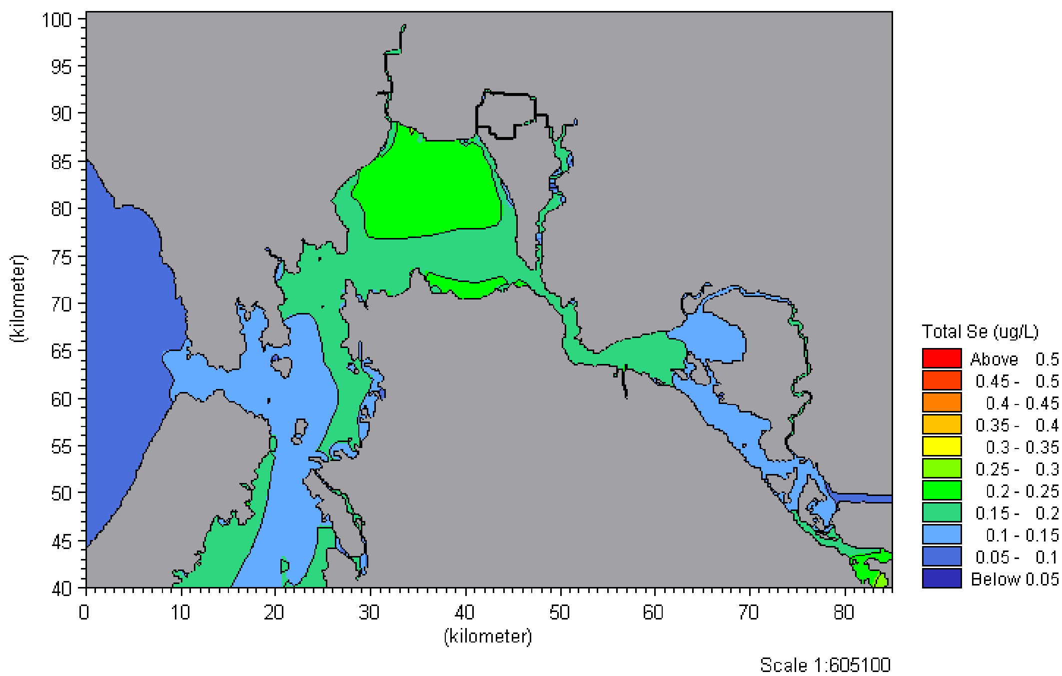
Near-Field Changes in Receiving Waters. Under worst-case ocean current conditions (i.e., zero velocity), the resulting Se plume for the modeled diffuser design would reach a concentration of 15 ppb at a depth of approximately 48 meters, or 12 meters above the diffuser, under both summer and winter temperature conditions. At this elevation, the plume would be approximately 3.1 meters wide and 87 meters long. Under maximum ocean current conditions (both summer and winter), the 15 ppb criterion would be achieved at a depth of approximately 59 meters, less than 1 meter above the diffuser ports. The plume would be approximately 1 meter wide and 85 meters long.

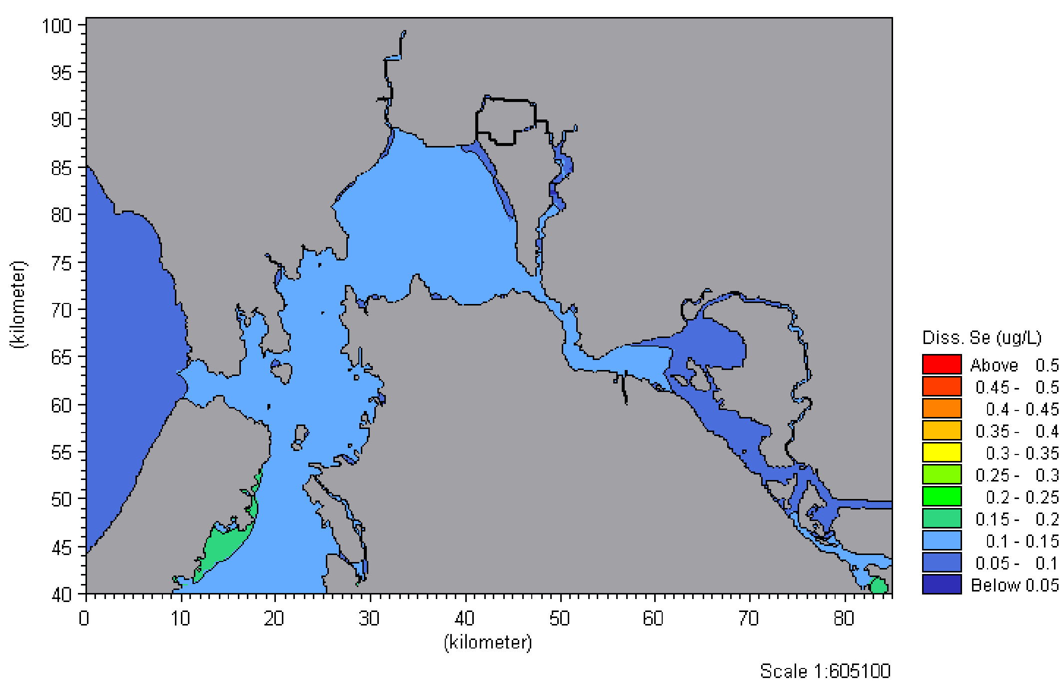
Far-Field Changes in Receiving Waters. Far-field changes were not modeled due to the high dilution capacity of the ocean environment and the location of the diffuser relative to the shoreline (1.44 miles offshore). Entrainment of discharged water (which is the cause of most far-field increases in concentration) is not envisioned to occur to a measurable degree outside of the mixing zone. Therefore, far-field impacts are not considered to be significant for the Ocean Disposal Alternative.

Impacts on Drinking Water Intakes. The closest water treatment facility plants are Lopez Water Treatment Plant in Arroyo Grande (22 miles inland from the ocean) and Lompoc Water Treatment Plant (40 miles inland from the ocean). Because no drinking water intakes are identified in the vicinity of this alternative, no negative impacts would occur.

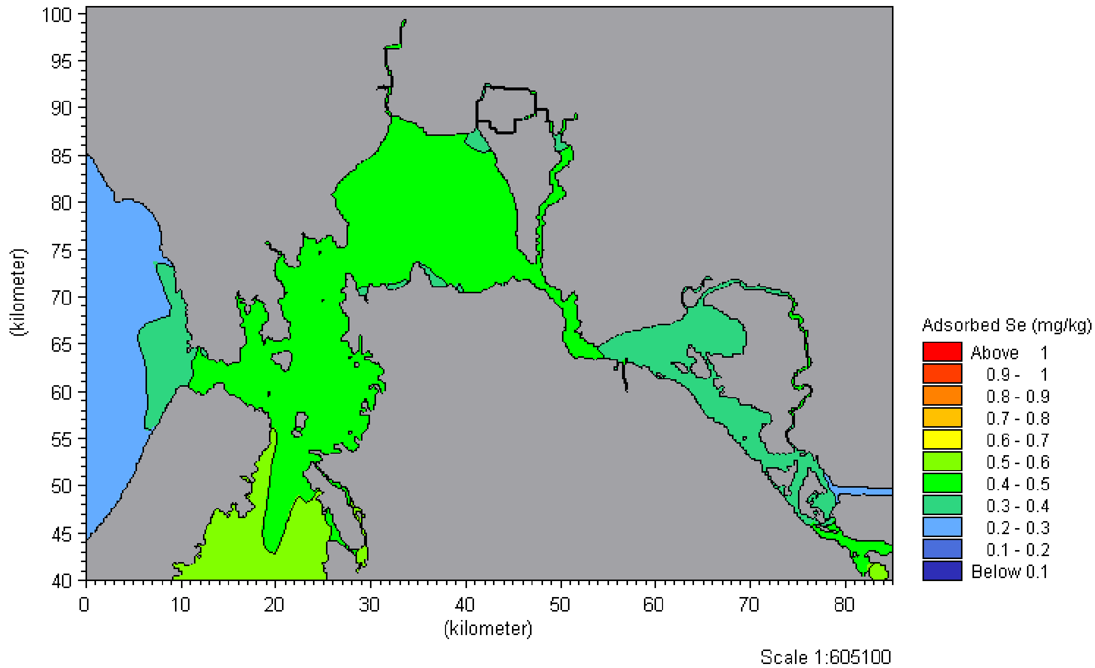
G1.1.2.5 Delta-Chipps Island Disposal Alternative

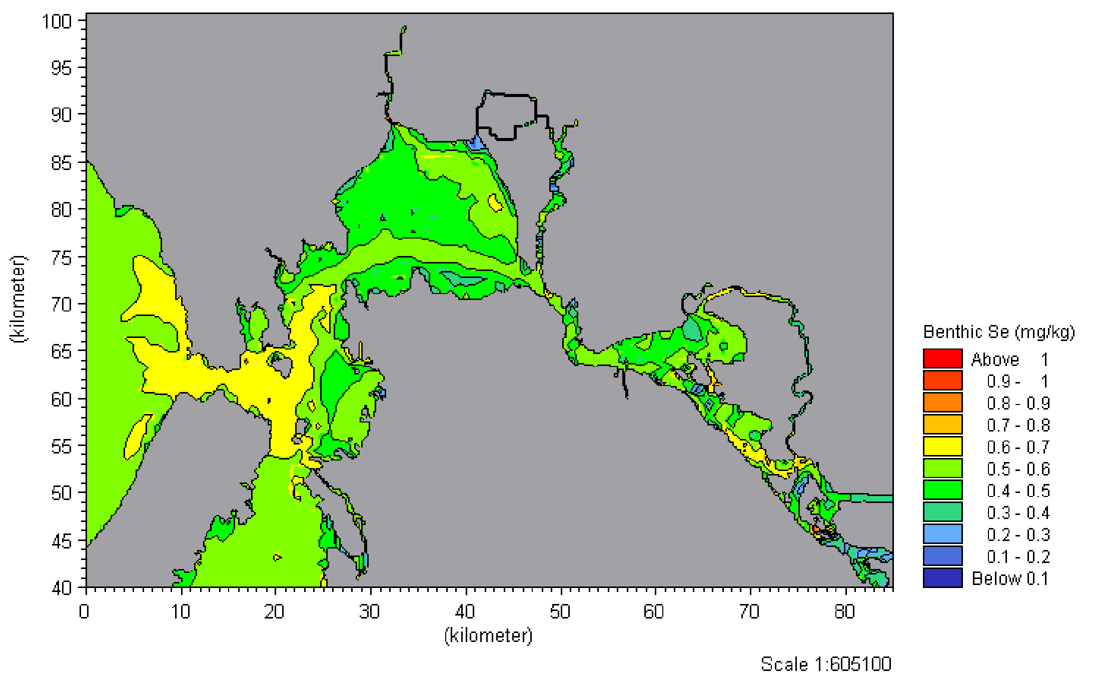
Under this alternative the drainwater would come from a treatment facility collector point at South Dos Palos through the existing San Luis Drain. The drainwater would be conveyed





URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Predicted Existing Conditions Total and Dissolved Selenium Concentrations (June-November 1997)	FIGURE G1-5c





URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Predicted Existing Conditions Adsorbed and Benthic Selenium Concentrations (June-November 1997)	FIGURE G1-5d

northwest through a new pipeline or open canal and two pump stations and be disposed of at a point south of Chipps Island. The outfall would be affected by ocean tides.

Construction Impacts

The conveyance system traverses through mostly flat and gently sloping land. Canals would be designed with a concrete lining to reduce infiltration. Construction impacts would be mainly limited to soil erosion and resultant turbidity of surface streams.

Operational Impacts

Near-Field Changes in Water Quality. Results for both Delta Disposal Alternatives are very similar. Under worst-case zero velocity conditions (both summer and winter), the resulting Se plumes would reach a concentration of 5 ppb (the CTR criterion) at a depth of approximately 3 meters. At this elevation, the plumes would be approximately 1.5 meters wide and would have traveled a horizontal distance of approximately 2.5 meters in the direction of the port angle. Under 0.91 meter/second current conditions (both summer and winter), the 5 ppb criterion would be achieved at a depth of approximately 5 meters, less than 2 meters above the diffuser ports. At this elevation the plumes would be approximately 1 meter wide and would have traveled a horizontal distance of approximately 0.5 meter in the direction of the port angle. The 5 ppb plume produced by the first diffuser alternative would extend approximately 60 meters across the river channel, and would be continuous and relatively localized over the diffuser. The 5 ppb plume produced by the second diffuser alternative would extend over approximately 200 meters of the cross section, but would resemble 70 smaller individual plumes, one above each diffuser port.

Far-Field Changes in Water Quality.

FDM-Predicted Changes in TDS Concentrations. In the 35-year simulations, 19.7 kilograms per second of salt added at a constant flow rate into the Delta at Chipps Island and the TDS increment at Suisun Bay, Rock Slough, Martinez, and Clifton Court Forebay was tracked for the 35-year period. The basic results of these simulations are shown on Figure G1-6, which presents the mean TDS increment that is predicted to occur at Suisun Bay and at the CCWD export point at Rock Slough. The predicted TDS increments at Martinez and Clifton Court Forebay are shown on Figure G1-7. As shown on both figures, the maximum impact of the agricultural discharge is predicted to have occurred in the 1977 drought period.

With the results of the simulations available as a time series it is possible to determine the frequency with which specified TDS would be attained at each of the sampling locations. These results provide the probability of a given salinity level being exceeded in any month of the year, or for any randomly selected year.

The TDS exceedance probabilities computed from the analysis are presented on Figures G1-8, G1-9, and G1-10 for Suisun Bay, Rock Slough, and Clifton Court Forebay, respectively. These data show that based on the 30-year sequence of flows the increase in TDS (salinity) at Suisun Bay could be expected to exceed 40 ppm with an approximate probability of 60 percent, and exceed 80 ppm with an approximate probability of 7 percent. For the Contra Costa intake at Rock Slough the simulation data show the probability that a 5 ppm TDS increment would be exceeded about 30 percent of the time. For the Contra Costa intake at Rock Slough the computed TDS concentration increment never

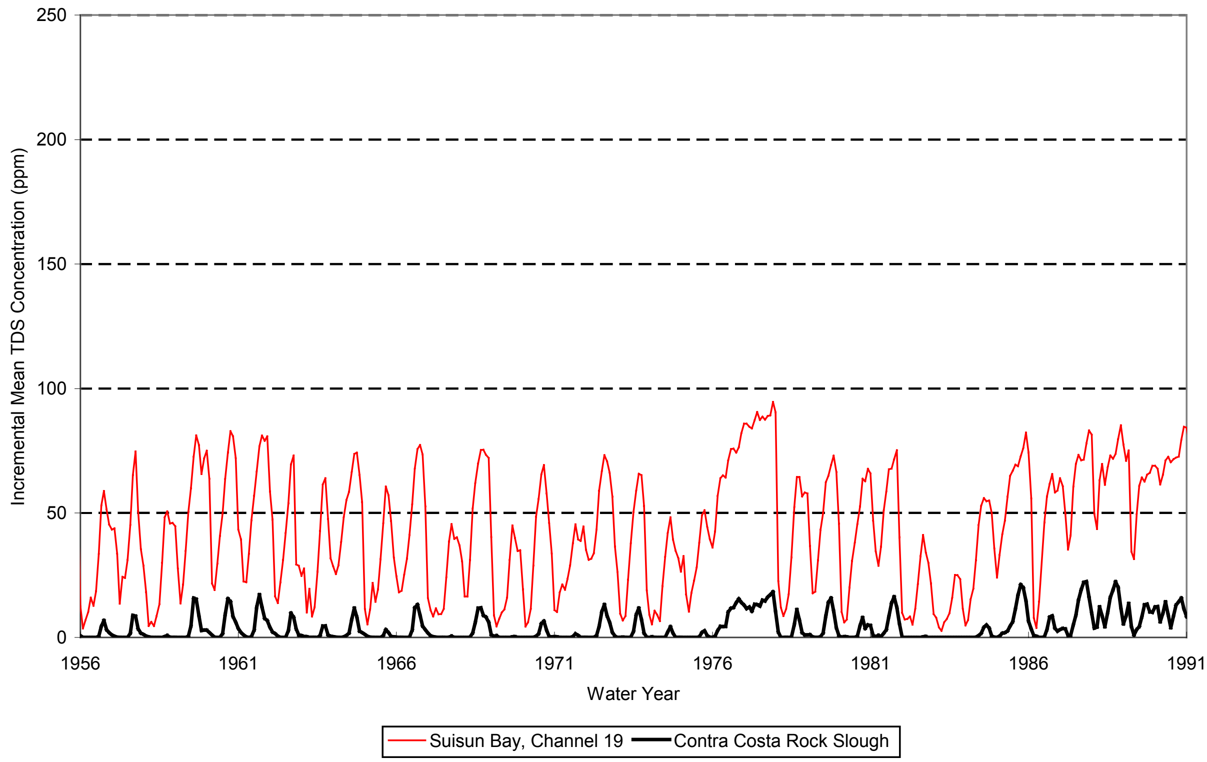


Figure G1-6 Chipps Island Discharge, 1956-91 Mean TDS Increment from 41 cfs Discharged at 17,000 ppm

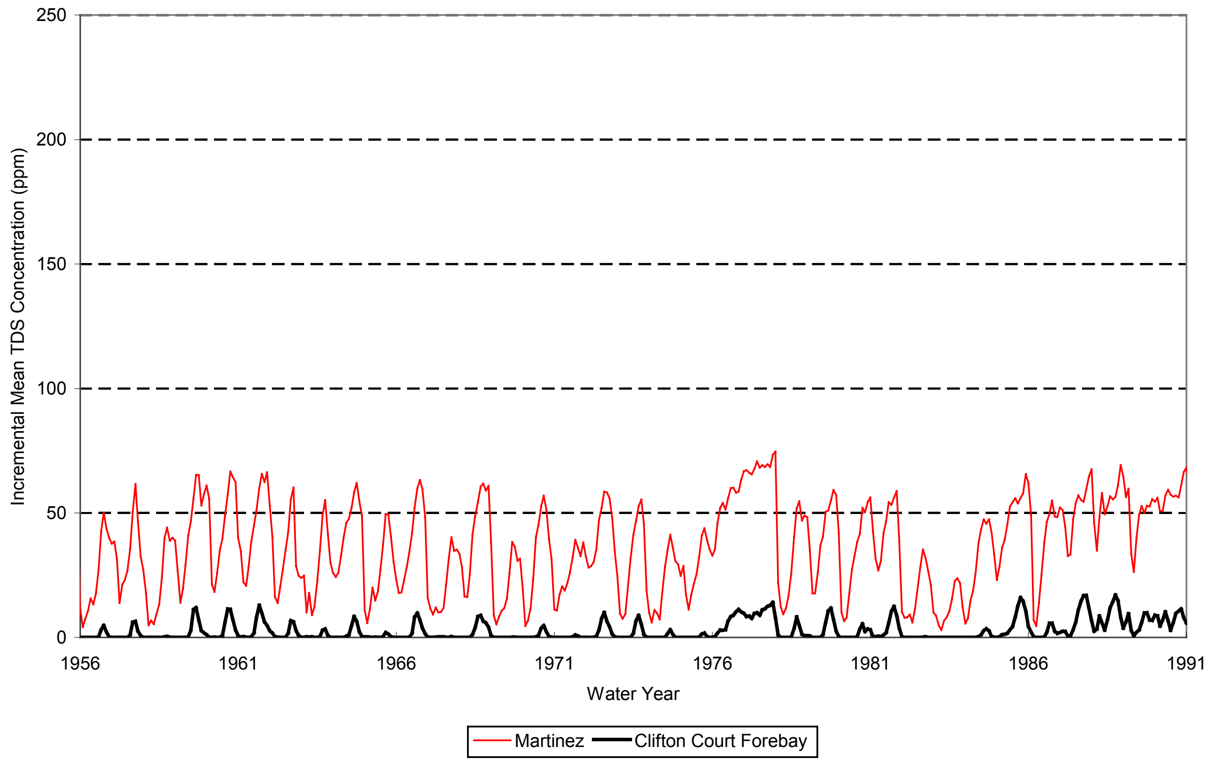


Figure G1-7 Chipps Island Discharge, 1956-91, Mean TDS Increment from 41 cfs Discharged at 17,000 ppm

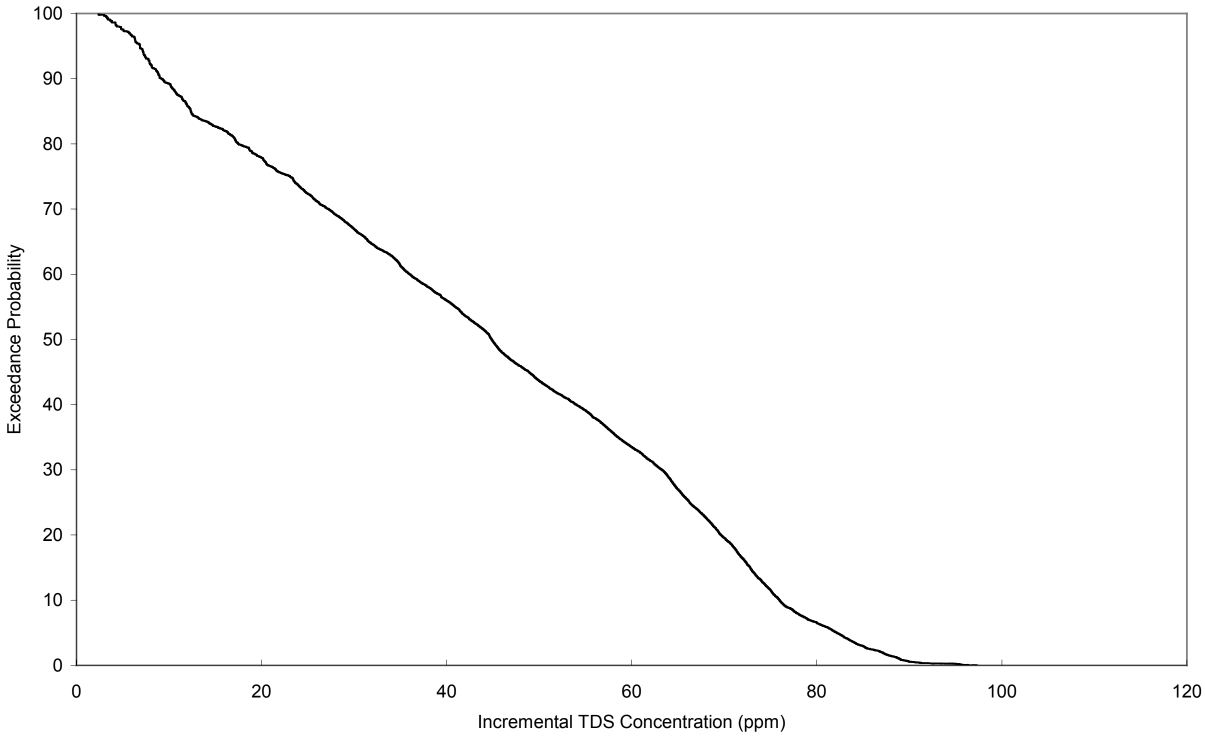


Figure G1-8 Exceedance Probability for Incremental TDS (Salinity) at Suisun Bay, Channel 19, Chipps Island Discharge, 1956-91, All Months, 41 cfs at 17,000 ppm

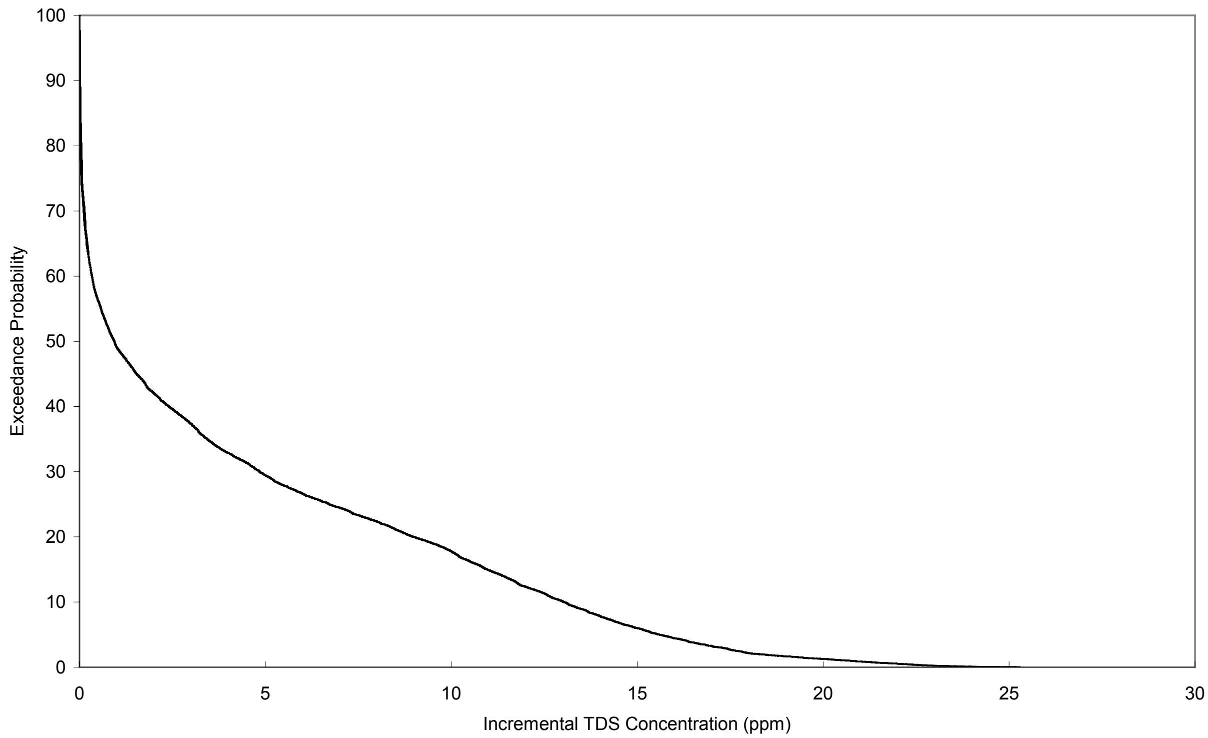


Figure G1-9 Exceedance Probability for Incremental TDS (Salinity) at Contra Costa Rock Slough Intake, Chipps Island Discharge, 1956-91, All Months, 41 cfs at 17,000 ppm

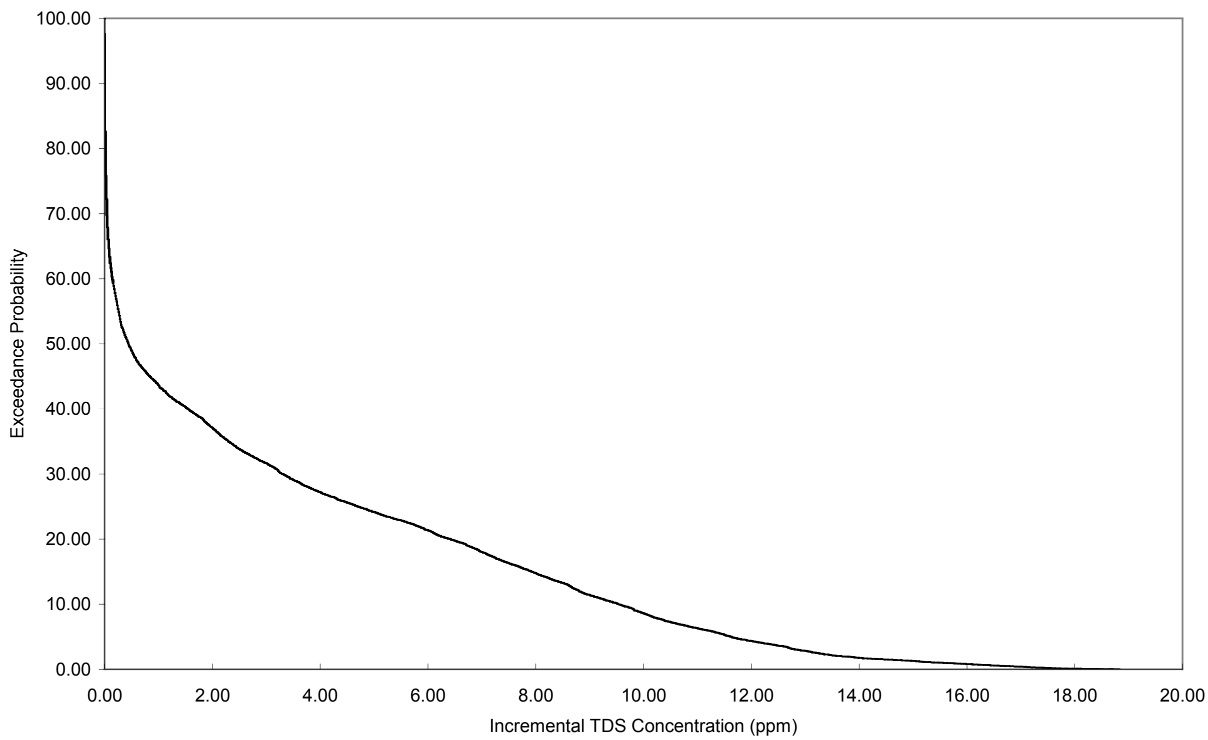


Figure G1-10 Exceedance Probability for Incremental TDS (Salinity) at Clifton Court Forebay, Chipps Island Discharge, 1956-91, All Months, 41 cfs at 17,000 ppm

exceeded 25 ppm. At Clifton Court Forebay the computed salinity increment exceeded 10 ppm less than 10 percent of the time.

The simulation data also allow computation of monthly mean increments in TDS at the three locations considered. For example, Figure G1-11 shows the 22-year mean TDS at Pittsburg together with the predicted mean monthly increment in TDS at nearby Suisun Bay from a discharge at Chipps Island of 41 cfs at 17,000 ppm TDS. Similar data are shown for the Contra Costa intake at Rock Slough and Clifton Court Forebay for each month of the year on Figures G1-12 and G1-13, respectively.

The results presented here correspond to a period that includes a very dry year (1977) and the effect of the reduced net Delta outflow in this period is very evident.

MIKE 21-Predicted Changes in TDS Concentrations. The location of points selected for time series extractions from the MIKE 21 Chipps Island simulation are shown on Figure G1-14. Predicted incremental TDS concentrations are generally less than 20 ppm at the drinking water intake at Oakley, 20 to 60 ppm at the Antioch intake, and 50 to 60 ppm at Chipps Island (Figures G1-15a and G1-15b). These incremental changes are less than 1 percent of existing TDS concentrations. The area with incremental changes between 35 and 40 ppm predominantly extends from Mare Island to Carquinez Strait (lower plot on Figure G1-15c). These concentrations are lower by a factor of approximately two from the FDM over the same simulation period, providing a range of model estimates.

Changes in Selenium Concentrations. Increases in total Se concentrations due to the Delta-Chipps Island Disposal Alternative are not predicted to cause exceedance of the 5 μg/L water quality objective (upper plot on Figure G1-16); however, increases in either dissolved concentrations or concentration adsorbed to suspended or benthic particulate matter may enhance bioaccumulation in marine organisms. Consequently, changes are expressed in this section relative to the dissolved and adsorbed parameters.

Predicted dissolved concentrations at six time-series monitoring stations shown on Figure G1-14 are generally between 0.1 and 0.25 μg/L (dark lines on Figure G1-17a). The exception is in the immediate vicinity of the discharge at Chipps Island, where concentrations are typically between 0.3 μg/L and as high as 0.5 μg/L. Although increases in dissolved concentration are less than 0.05 μg/L at the westernmost Red Rock station, they are as high as 0.25 μg/L near the Chipps Island discharge 10 percent of the time (Figure G1-17b). As illustrated by the upper plot on Figure G1-17c, the area affected by the discharge extends into San Pablo Bay, with increases between 0.1 and 0.2 μg/L in most of Suisun Bay (lower plot on Figure G1-17c).

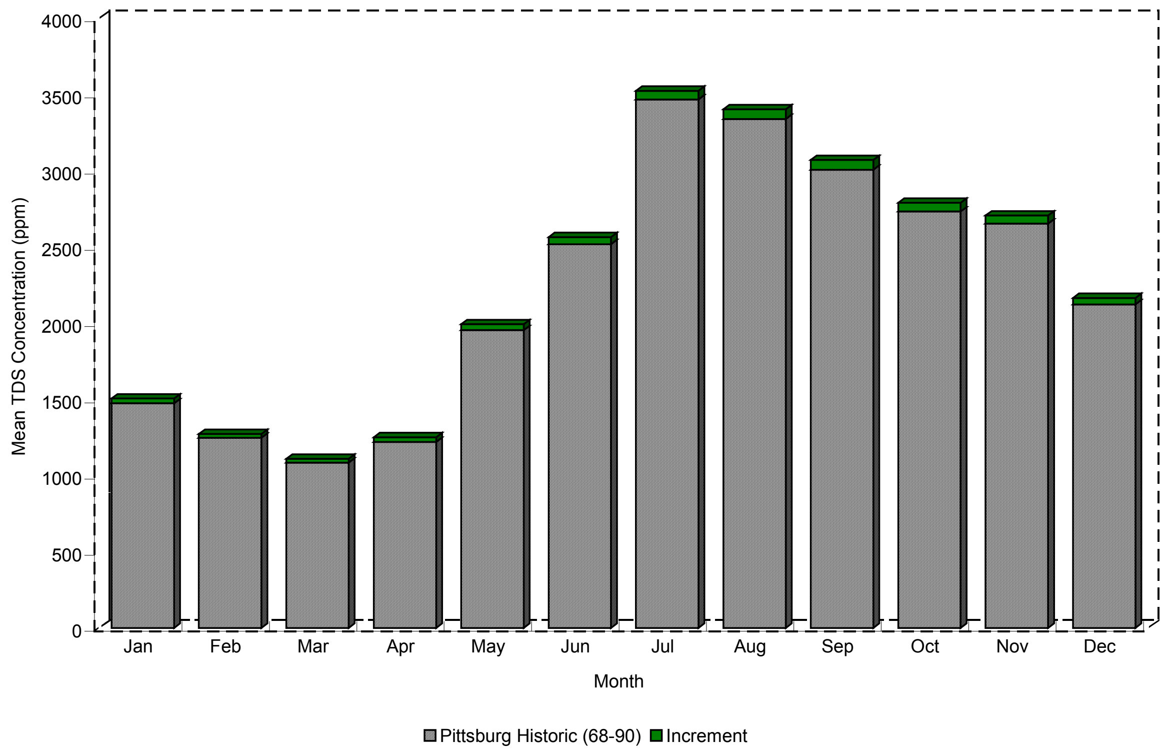


Figure G1-11 Suisun Bay, Channel 19, 1956-91, Monthly Mean TDS (Salinity), Mean TDS

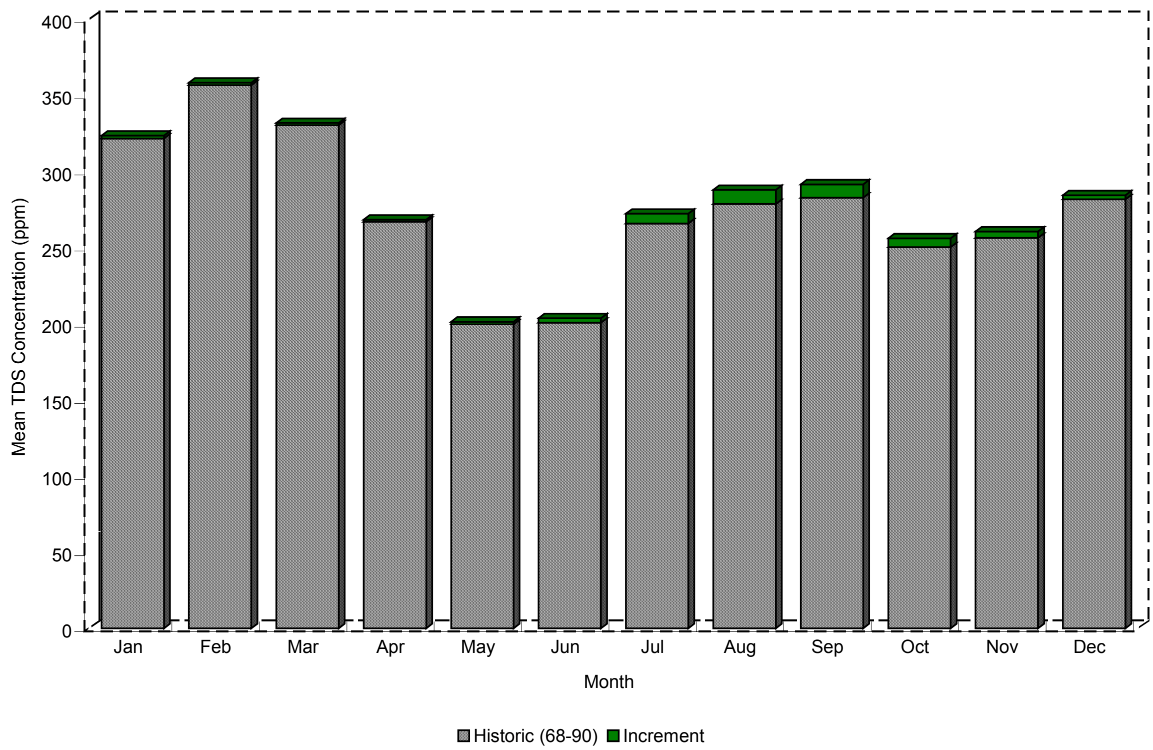


Figure G1-12 Contra Costa Intake - Rock Slough, 1956-91, Monthly Mean TDS (Salinity), Mean TDS + Incremental Increase from 41 cfs Discharge at Chipps Island

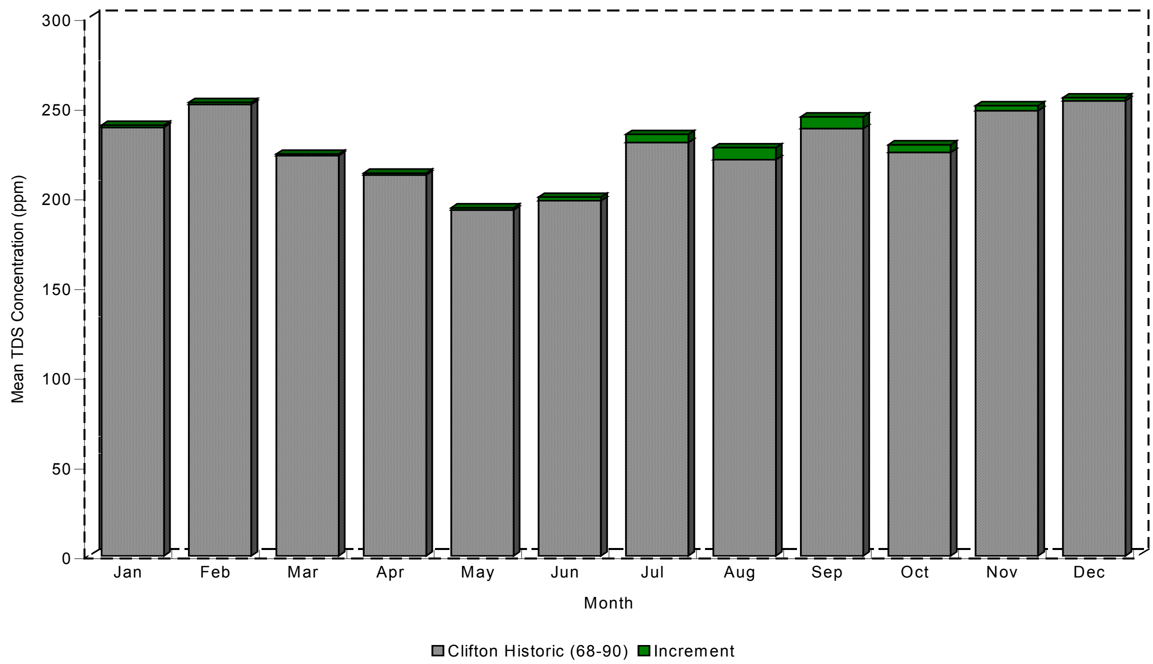
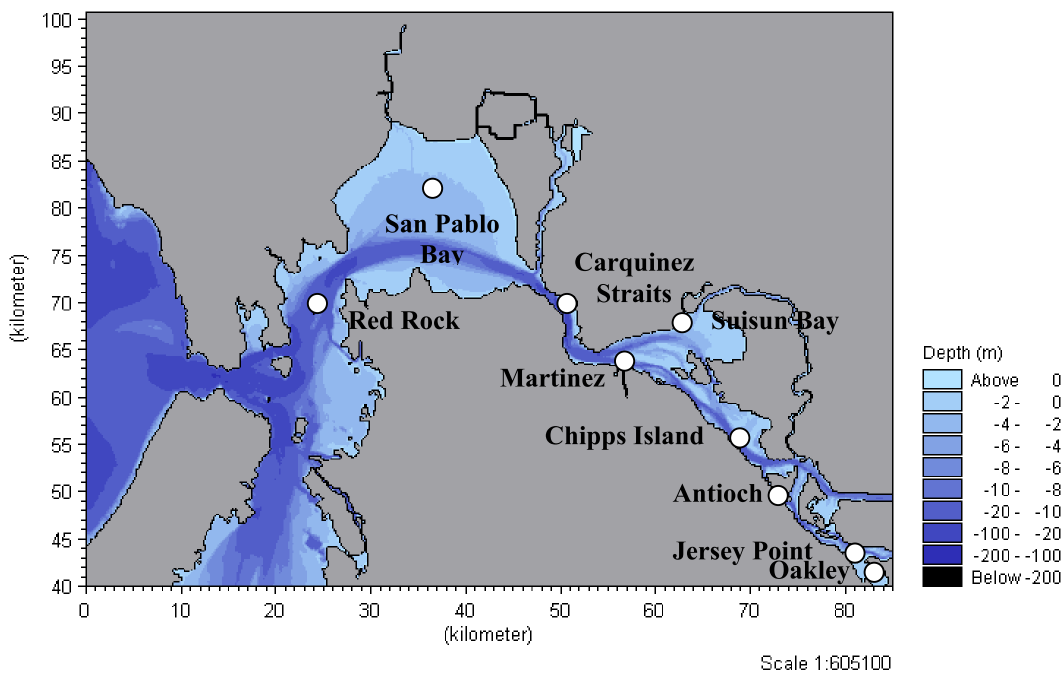
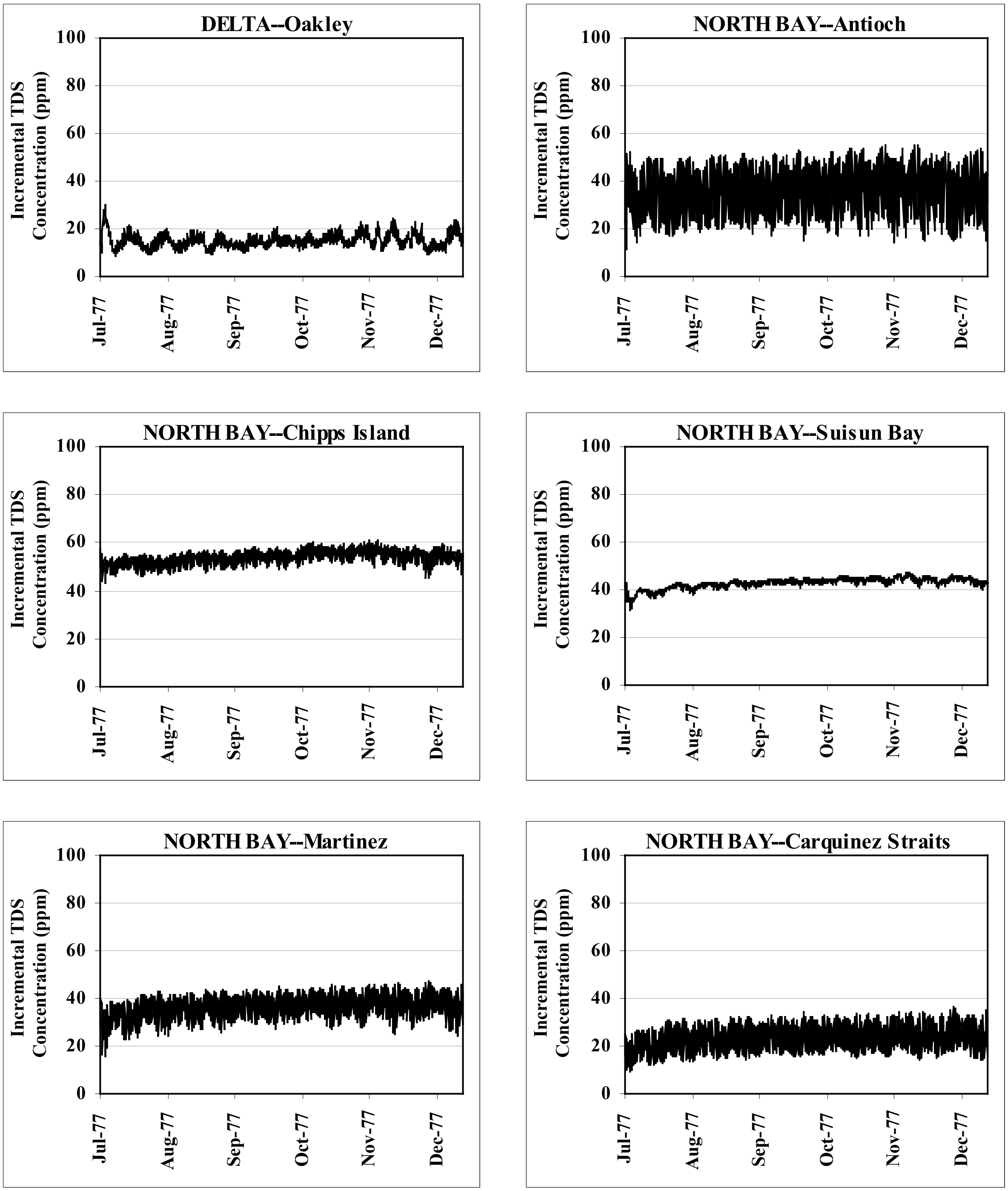


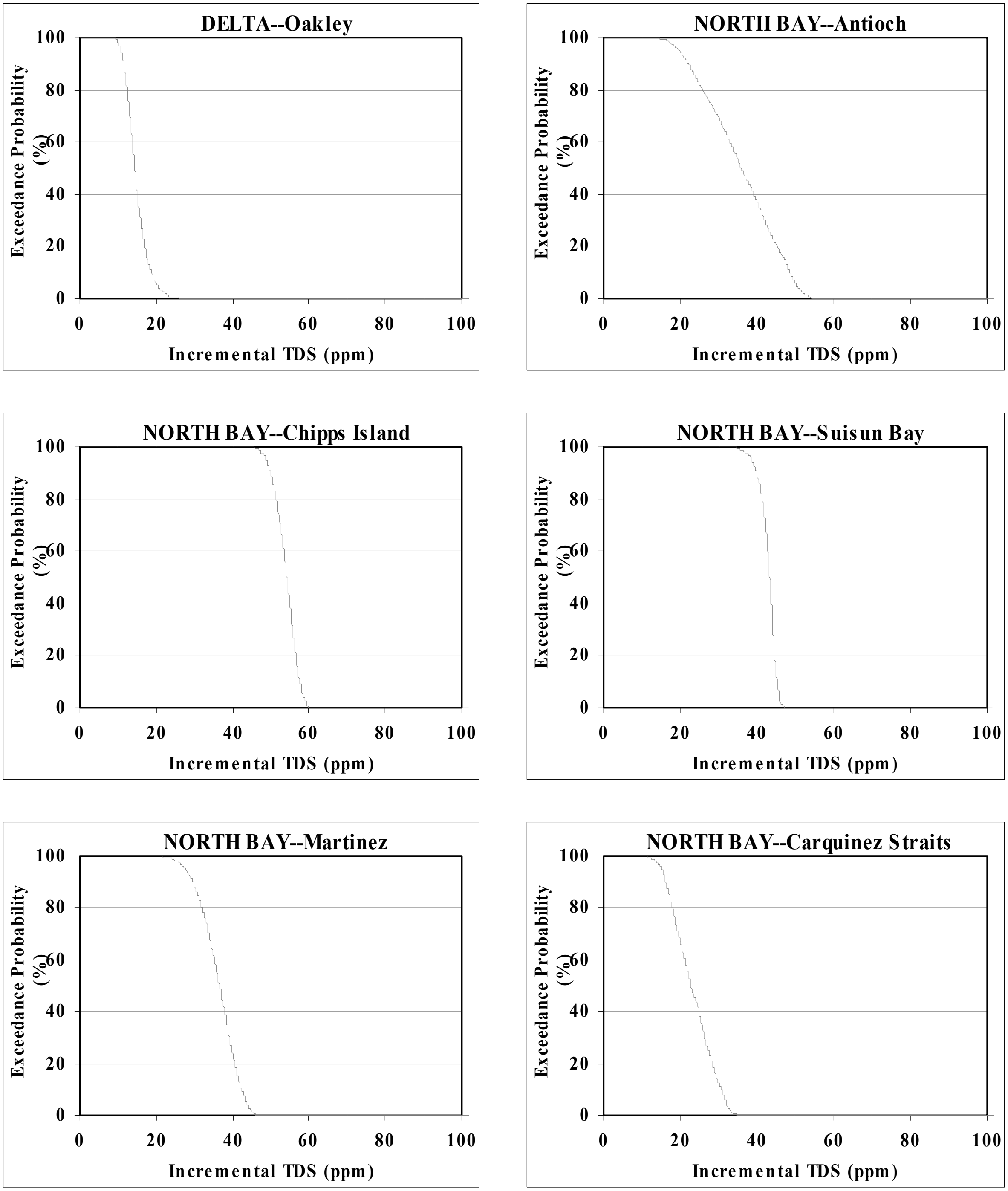
Figure G1-13 Clifton Court Forebay, 1956-91, Monthly Mean TDS (Salinity), Mean TDS + Incremental Increase from 41 cfs Discharge at Chipps Island



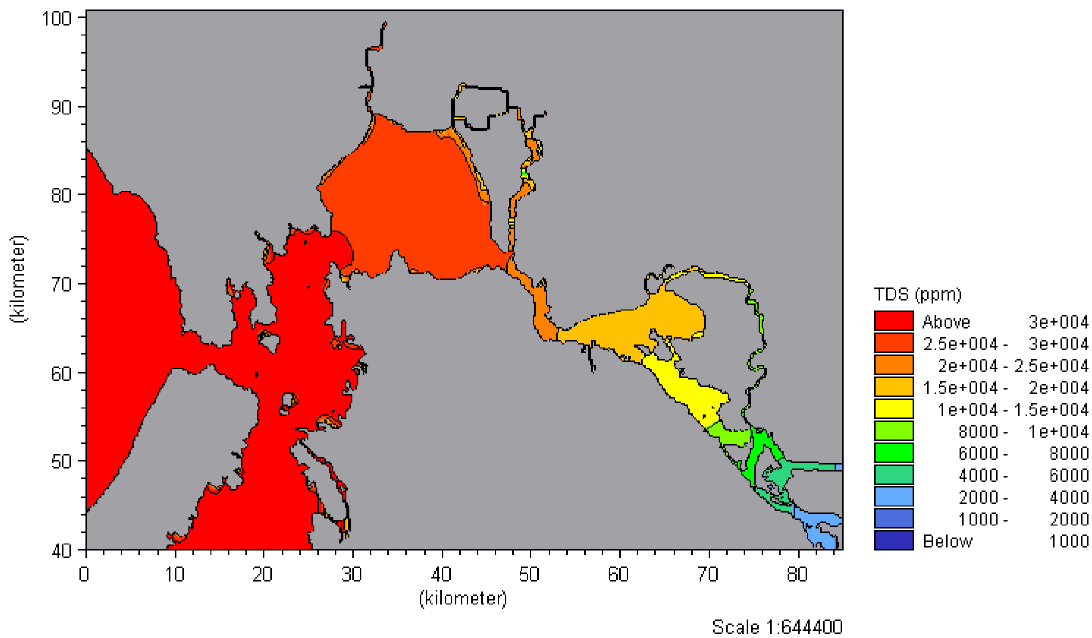
URS	17324004 San Luis Drainage Feature Re-evaluation	Bathymetry and Locations Selected for Time Series Analysis of TDS and Selenium Concentrations as a Function of Time	FIGURE G1-14

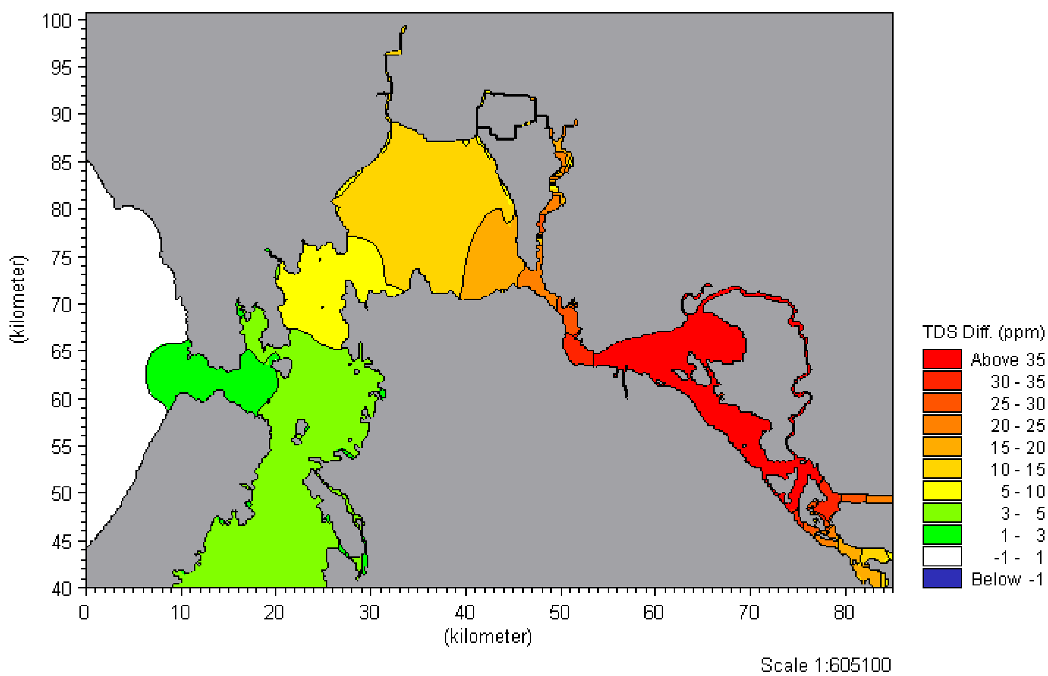


URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Chipps Island Discharge (July-Dec 1977) Total Dissolved Solids Concentrations Expressed as Incremental Change from Existing Conditions	FIGURE G1-15a

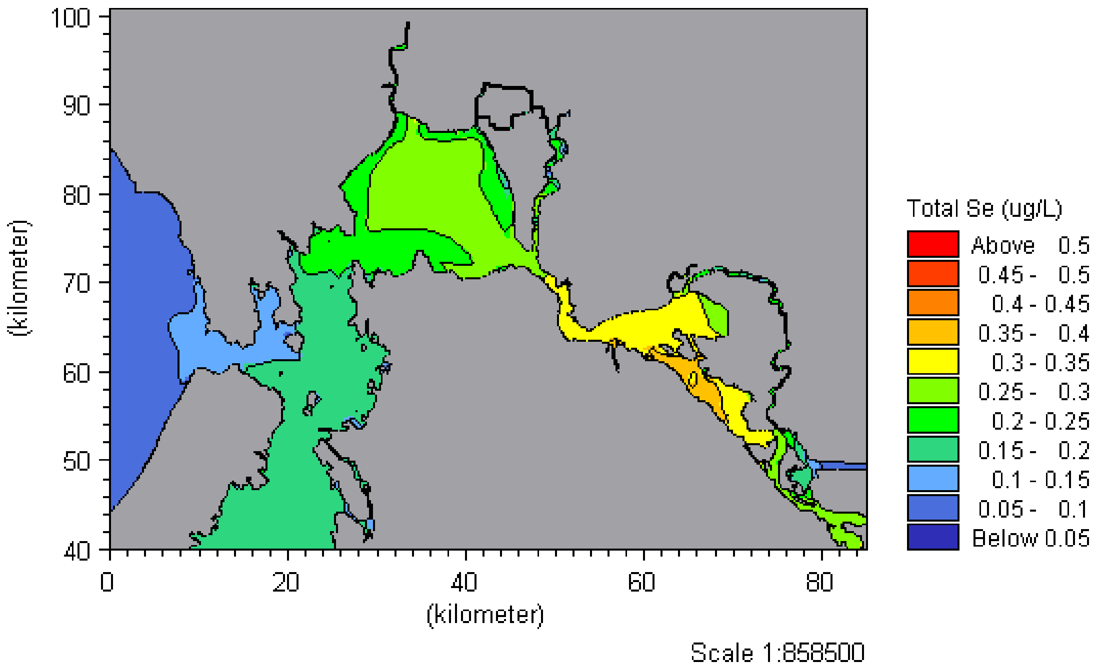


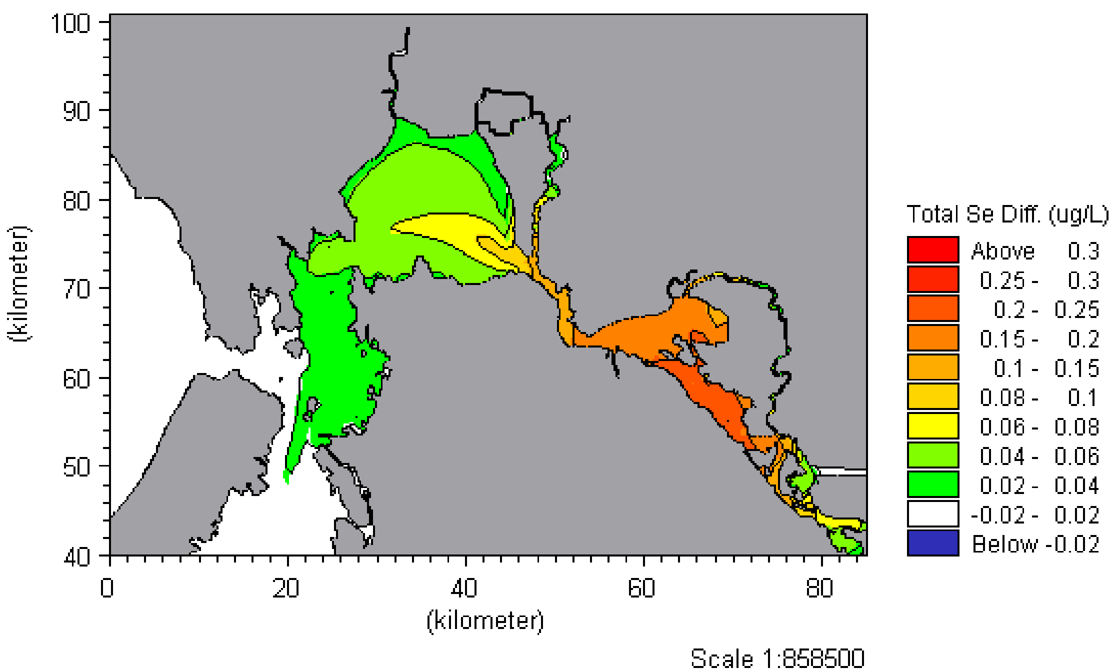
URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Chipps Island Discharge (July-Dec 1977) Probability of Exceedance of Incremental TDS Concentrations	FIGURE G1-15b



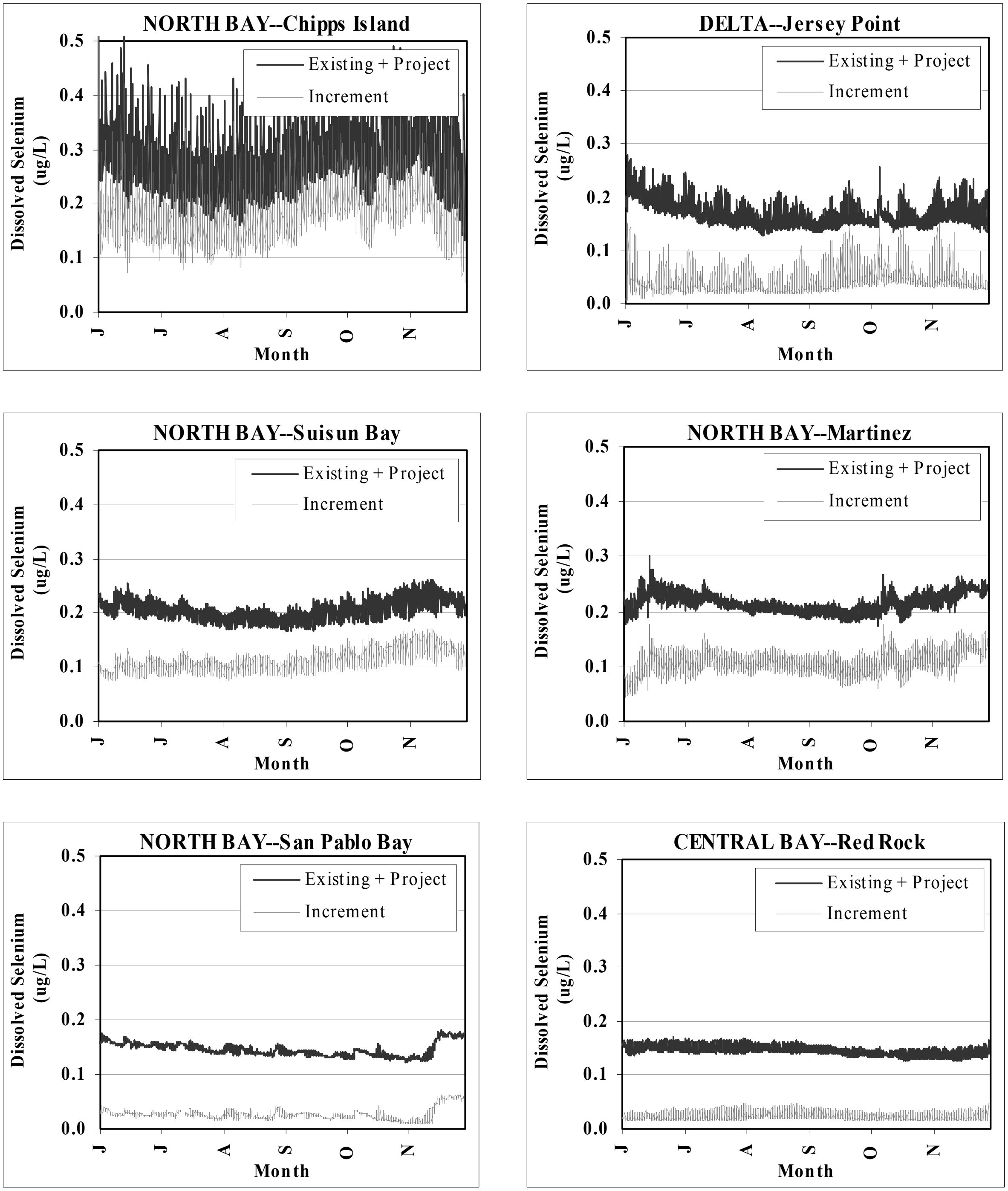


URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Chipps Island Discharge (July-Dec 1977) Mean Total Dissolved Solids Concentration (TOP) Difference from Existing Conditions (BOTTOM)	FIGURE G1-15c

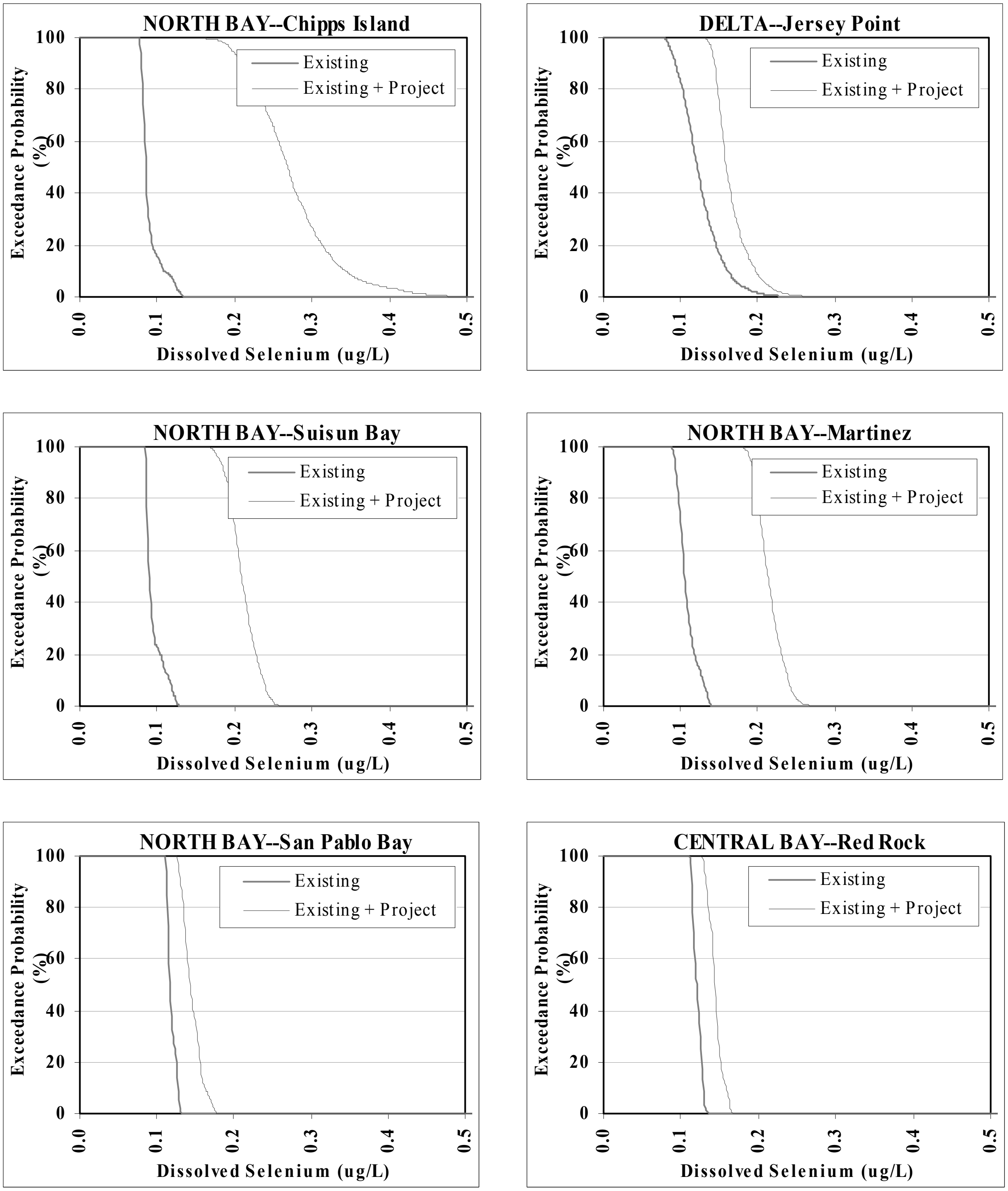




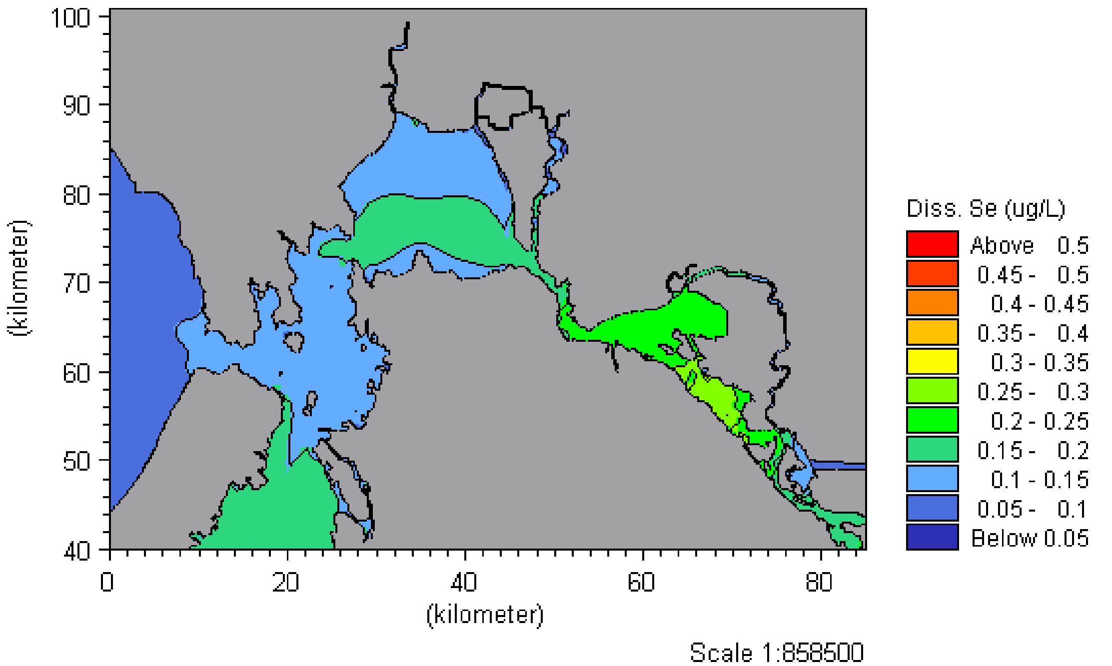
URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Chipps Discharge (July-November 1997) Mean Total Selenium Concentration (TOP) Difference from Existing Conditions (BOTTOM)	FIGURE G1-16

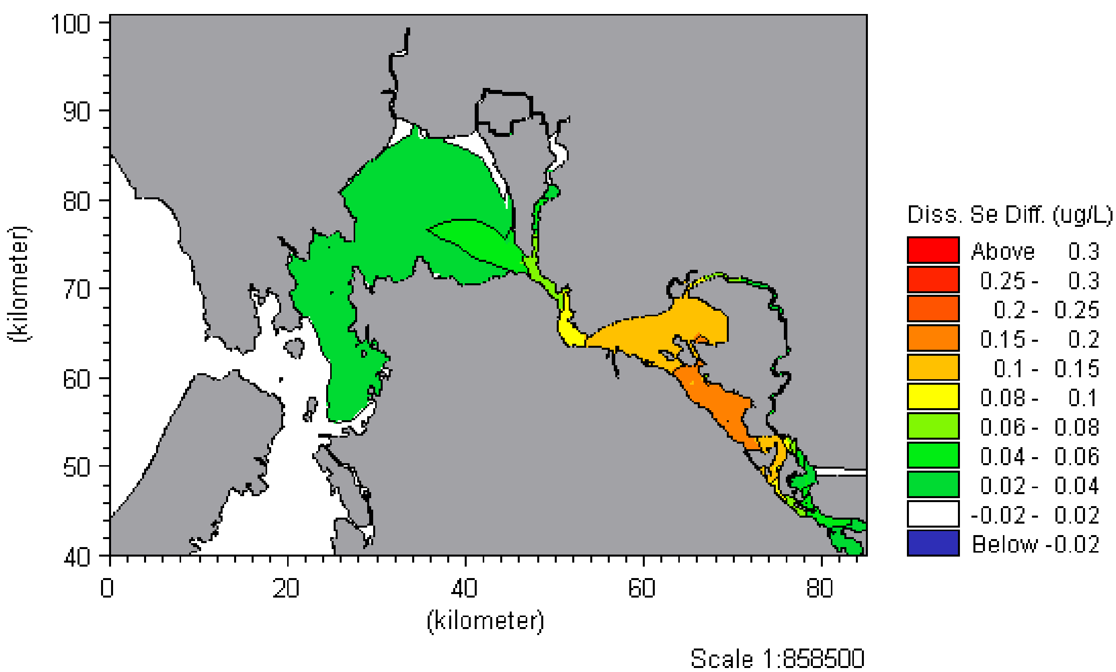


URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Chipps Discharge (June-November 1997) Dissolved Selenium Concentrations Due to Project and Incremental Change from Existing Conditions	FIGURE G1-17a



URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Chipps Discharge (June-November 1997) Probability of Exceedance of Dissolved Selenium Concentrations–Existing and Project Conditions	FIGURE G1-17b





URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Chipps Discharge (June-November 1997) Mean Dissolved Selenium Concentration (TOP) Difference from Existing Conditions (BOTTOM)	FIGURE G1-17c

Predicted adsorbed Se concentrations on suspended sediment are generally 0.6 to 1.0 mg/kg from the Delta to Suisun Bay, and 0.4 to 0.6 mg/kg in San Pablo and Central bays (dark lines on Figure G1-18a). Although increases in adsorbed concentration are less than 0.2 mg/kg at the westernmost Red Rock station, they are as high as 0.66 mg/kg near the Chipps Island discharge 10 percent of the time (Figure G1-18b). Similar to dissolved Se, the area affected by the discharge extends into San Pablo Bay (top plot on Figure G1-18c), causing increases between 0.35 and 0.45 mg/kg in most of Suisun Bay (bottom plot on Figure G1-18c).

Predicted adsorbed Se concentrations on benthic sediment vary between 0.2 and 1.0 mg/kg, with the highest concentrations at the discharge location at Chipps Island (dark lines on Figure G1-19a). Part of the explanation for the lower concentrations at Jersey Island is that the majority of sediment transported and ultimately deposited near there is from the Sacramento River (with an average adsorbed concentration on suspended sediment of 0.2 mg/kg). Similarly, most of the increases with time at the other stations are a direct consequence of the San Luis Drain discharge (compare dark and light lines on Figure G1-19a). Finally, the high Se concentrations on benthic sediment in the Central Bay are possibly a model artifact, where the effect of sand on the total benthic concentration cannot be included. As illustrated on Figures G1-19b and G1-19c (lower plot), is an incremental increase occurs in the benthic Se concentration generally between 0.01 and 0.05 mg/kg, but as high as 0.15 to 0.20 mg/kg near the discharge.

Summary of Impacts on Drinking Water Intakes. Based on numerical modeling at a flow of 41 cfs of drainwater to the Delta at Chipps Island, this alternative provides a negligible increase in the total estuary flow of salts and concentrations at the Rock Slough and Old River intakes. Se concentrations are also well below the limits for drinking water.

G1.1.2.6 Delta-Carquinez Strait Disposal Alternative

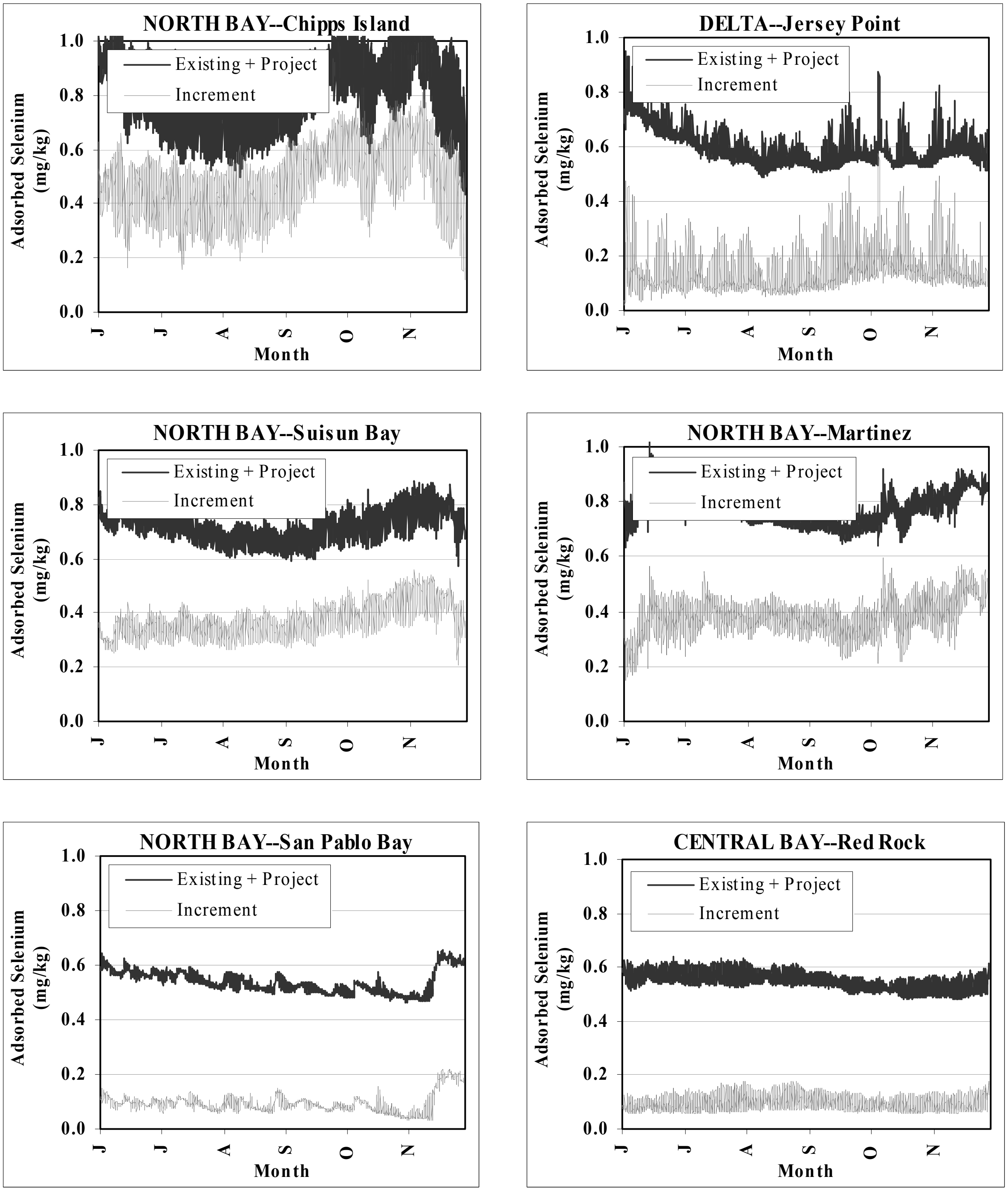
Under this alternative the drainwater will come from a treatment facility collector point at South Dos Palos through the existing San Luis Drain. The drainwater would be conveyed northwest through a new pipeline or open canal and two pump stations and be disposed of at a point in Carquinez Strait near the community of Crockett. The outfall would be affected by ocean tides.

Construction Impacts

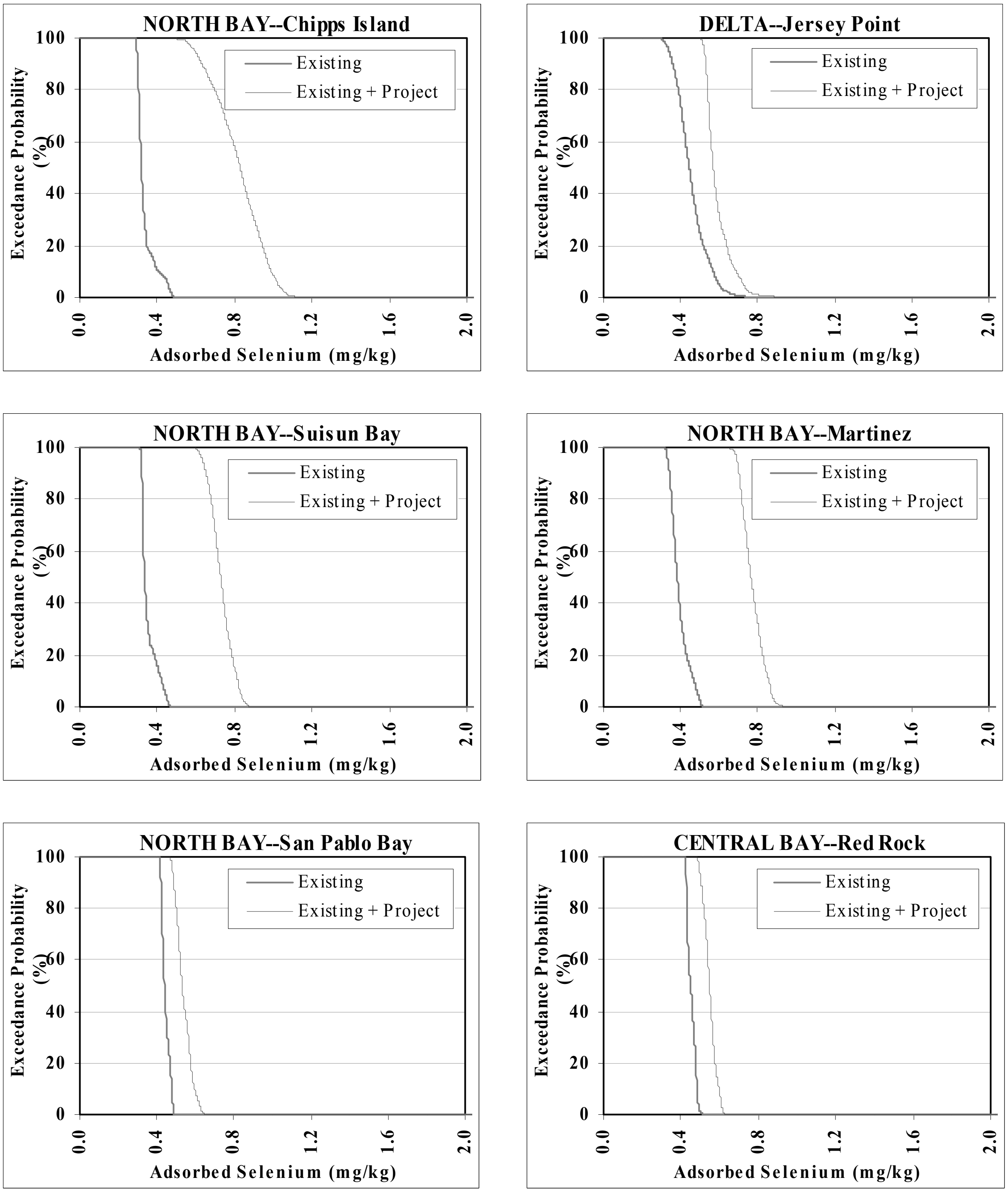
The conveyance system traverses through mostly flat and gently sloping land. Canals would be designed with a concrete lining to reduce infiltration. Construction impacts would be mainly limited to soil erosion and resultant turbidity of surface streams.

Operational Impacts

Near-Field Changes. Results for both Delta diffuser alternatives are very similar. As described under the Delta-Chipps Island Disposal Alternative section above under worst-case zero velocity conditions (both summer and winter), the resulting Se plumes would reach a concentration of 5 ppb (the CTR criterion) at a depth of approximately 3 meters. At this elevation, the plumes would be approximately 1.5 meters wide and would have traveled a horizontal distance of approximately 2.5 meters in the direction of the port angle. Under 0.91-meter/second current conditions (both summer and winter), the 5 ppb criterion would be achieved at a depth of approximately 5 meters, less than 2 meters above the diffuser ports. At this elevation the plumes would be approximately 1 meter wide and would have traveled a horizontal distance of approximately 0.5 meter in the direction of the port angle. The 5 ppb plume produced by the first



URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21Chipps Discharge (June-November 1997) Adsorbed Selenium Concentrations Due to Project and Incremental Change from Existing Conditions	FIGURE G1-18a



URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21Chipps Discharge (June-November 1997) Probability of Exceedance of Adsorbed Selenium Concentrations–Existing and Project Conditions	FIGURE G1-18b

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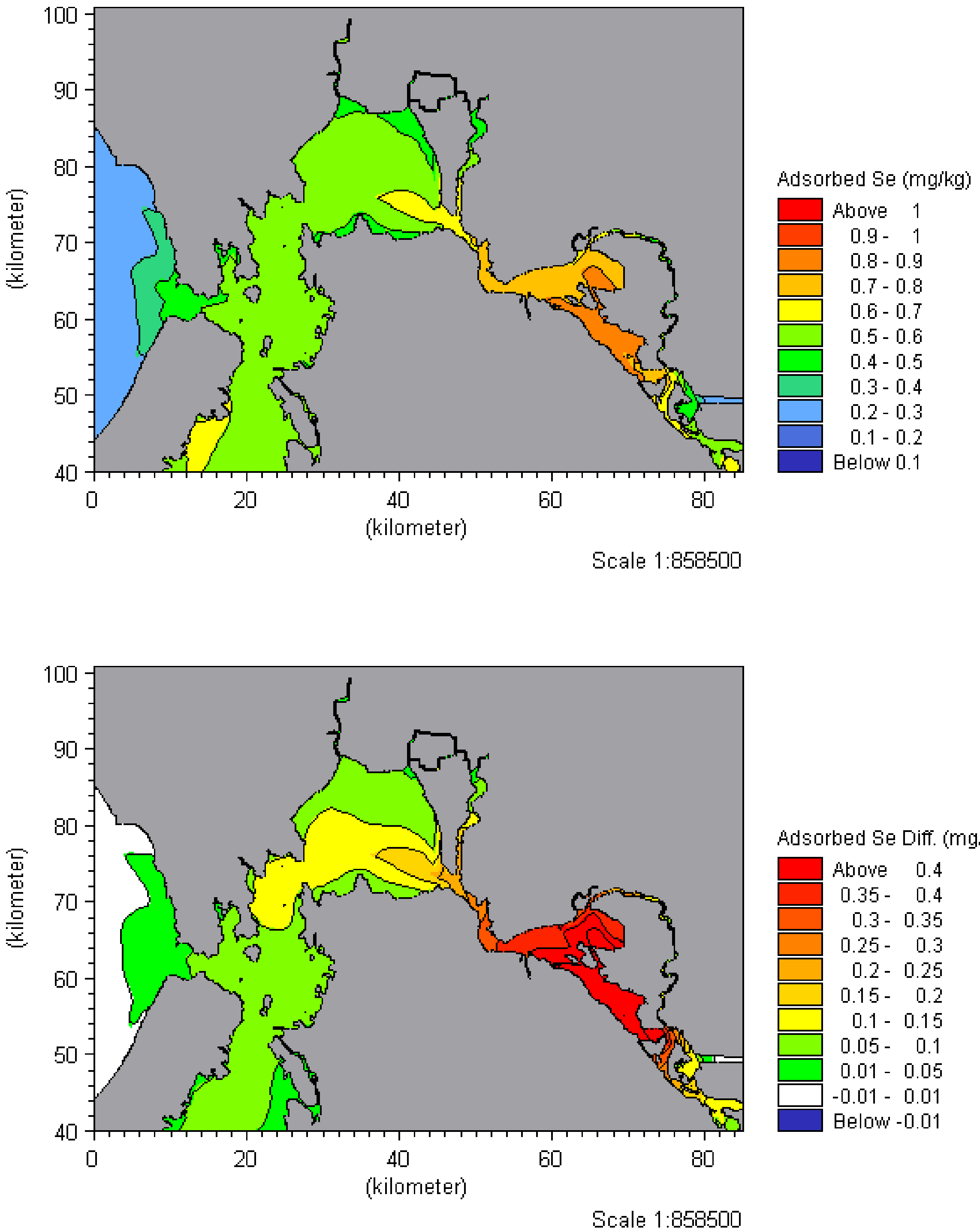
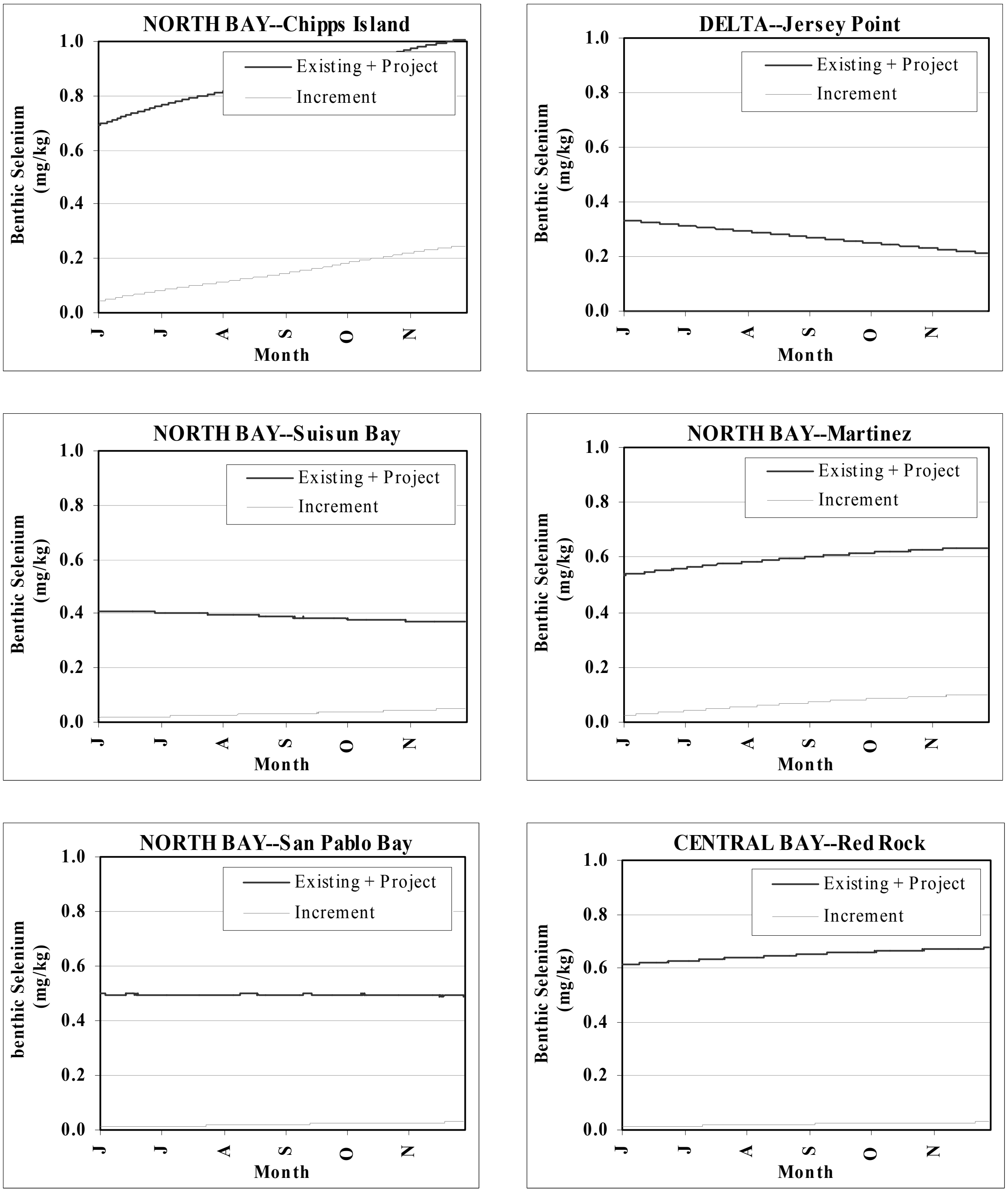


URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Chipps Discharge (June-November 1997) Mean Adsorbed Selenium Concentration (TOP) Difference from Existing Conditions (BOTTOM)	FIGURE G1-18c



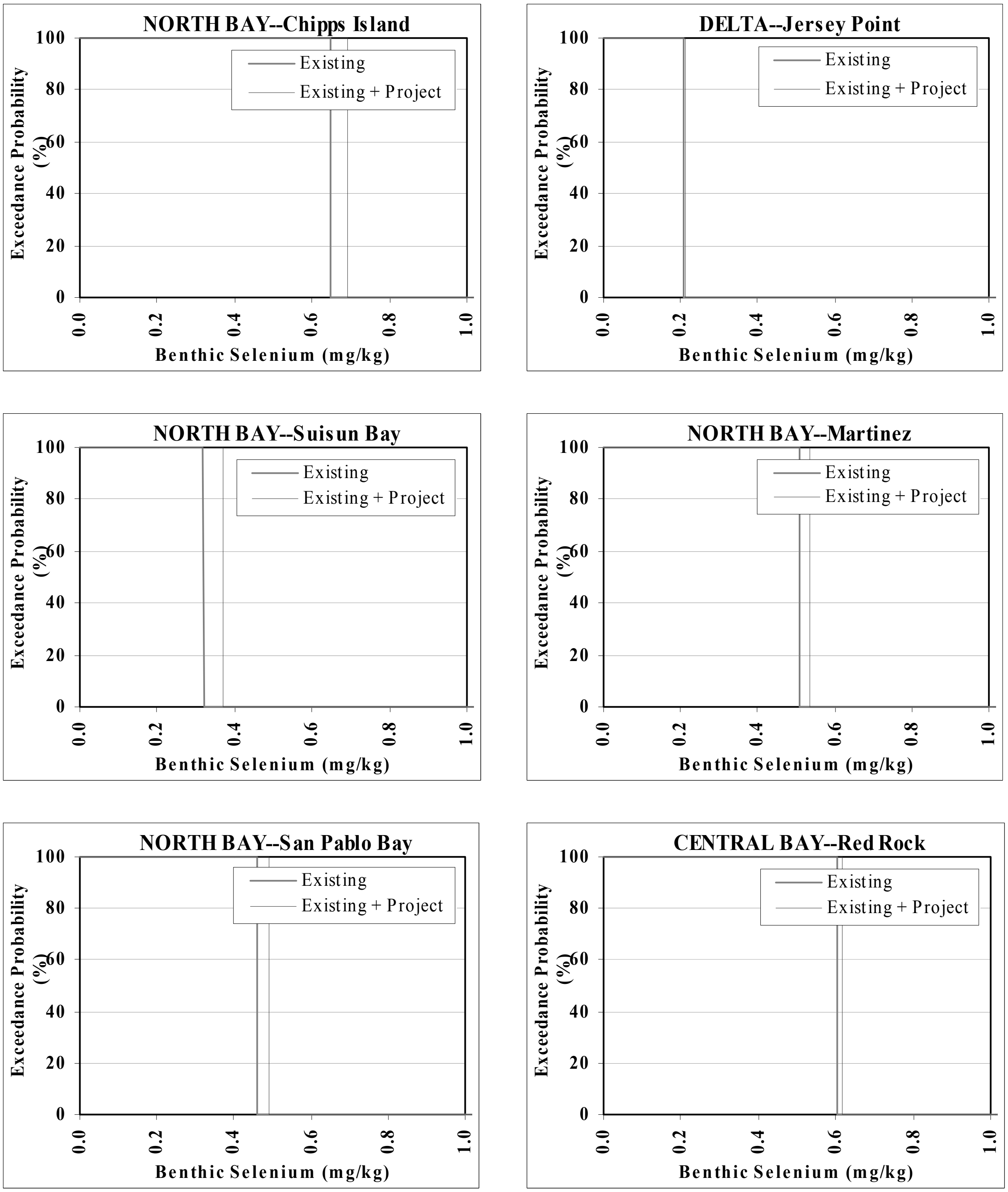
URS

17324004

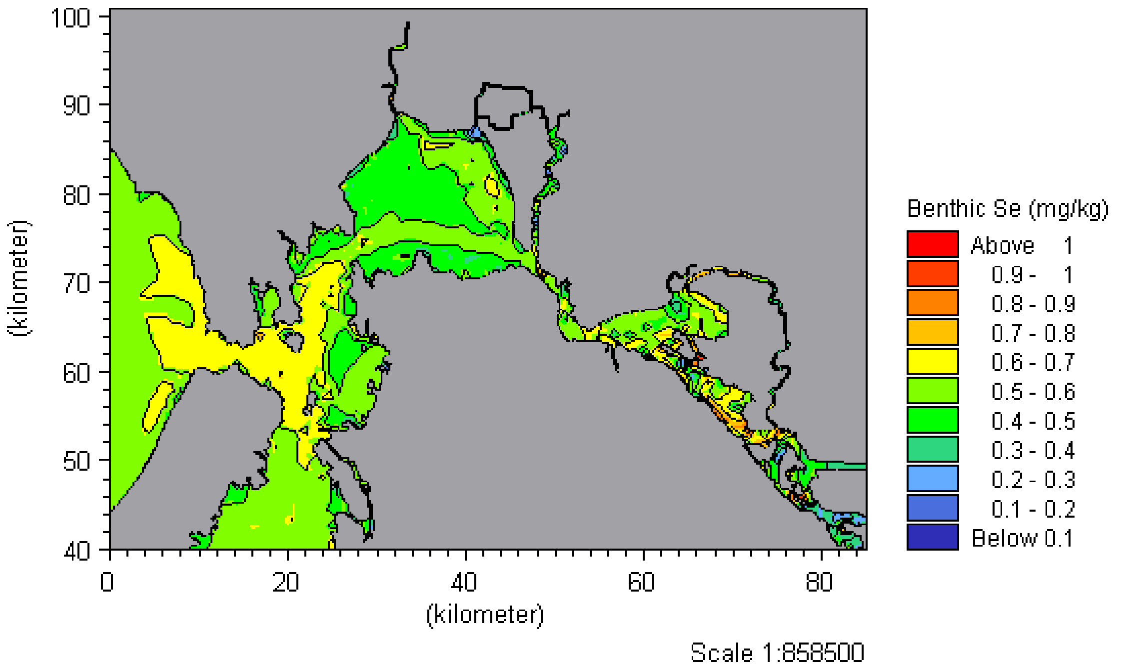
San Luis Drainage Feature Re-evaluation

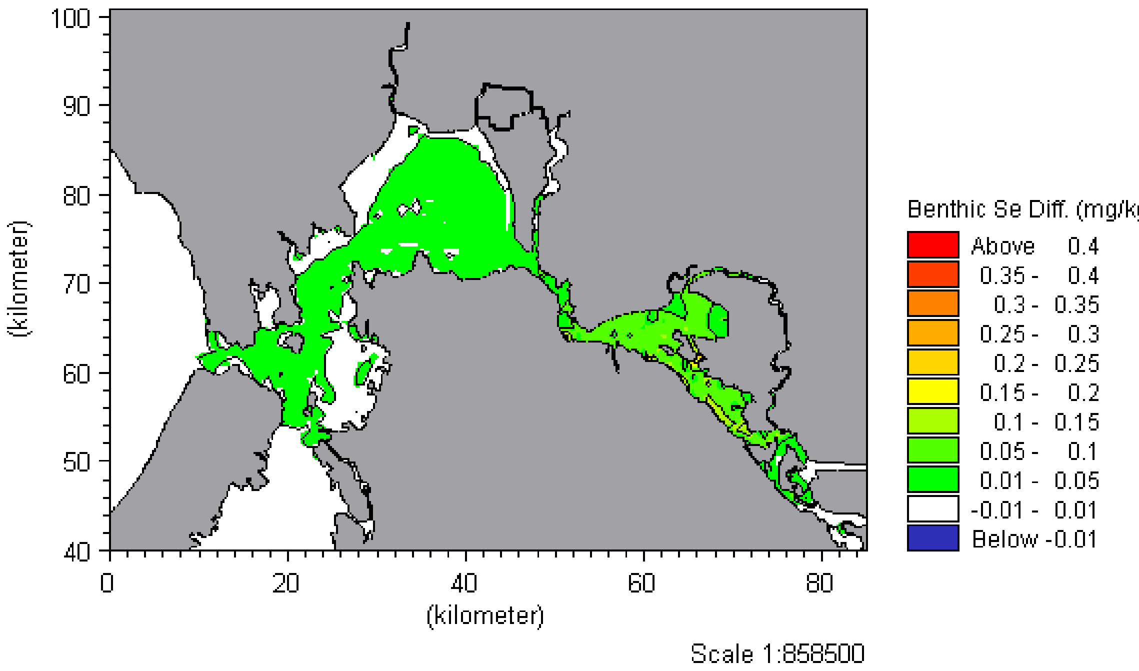
MIKE 21 Chipps Discharge (June-November 1997) Benthic Selenium Concentrations Due to Project and Incremental Change from Existing Conditions

FIGURE G1-19a



URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21Chipps Discharge (June-November 1997) Probability of Exceedance of Benthic Selenium Concentrations–Existing and Project Conditions	FIGURE G1-19b





URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Chipps Discharge (June-November 1997) Mean Benthic Selenium Concentration (TOP) Difference from Existing Conditions (BOTTOM)	FIGURE G1-19c

diffuser alternative would extend approximately 60 meters across the river channel, and would be continuous and relatively localized over the diffuser. The 5 ppb plume produced by the second diffuser alternative would extend over approximately 200 meters of the cross section, but would resemble 70 smaller individual plumes, one above each diffuser port.

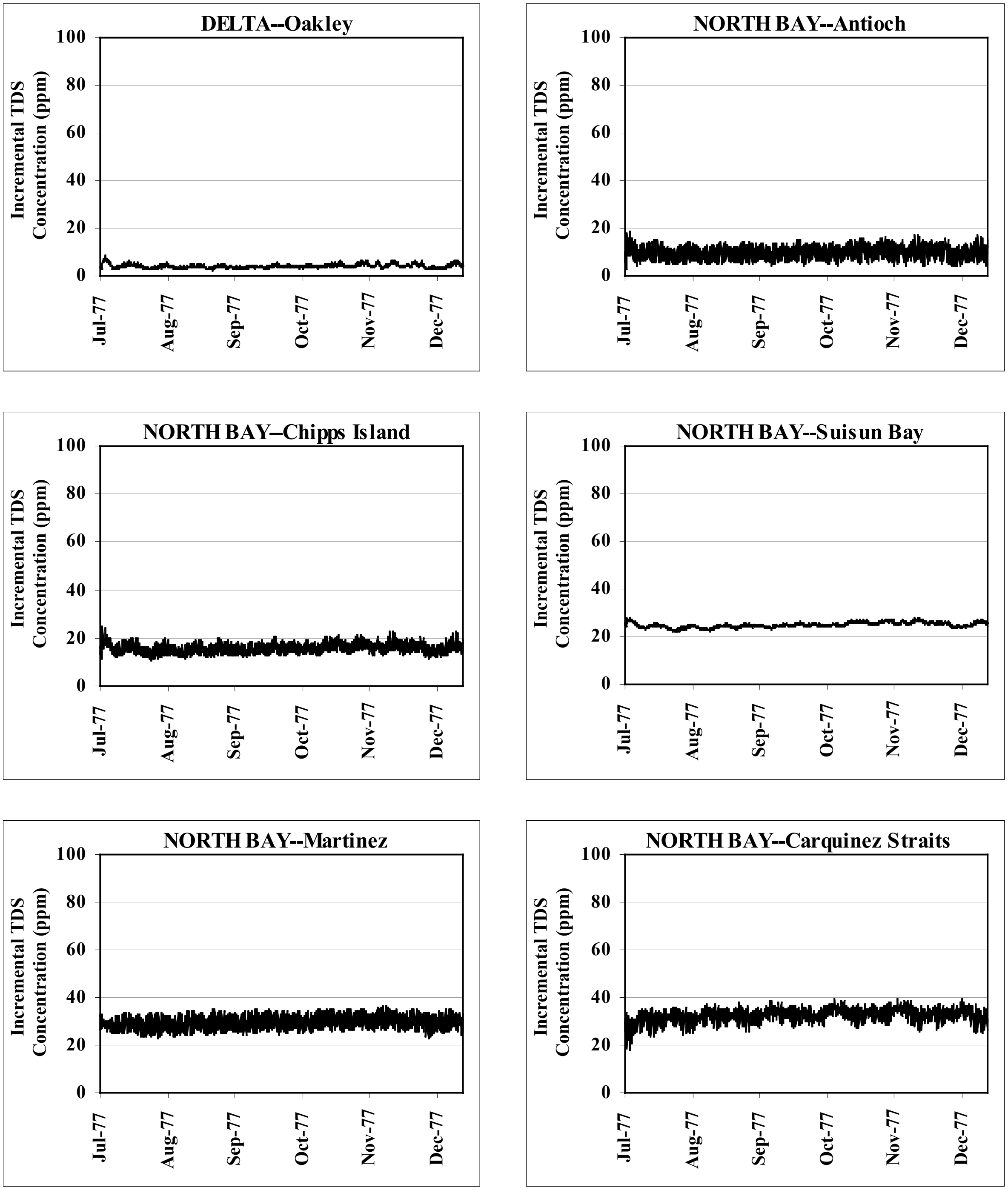
Far-Field Changes.

Changes in TDS Concentrations. Predicted incremental TDS concentrations at the time-series monitoring stations shown on Figure G1-14 are less than 10 ppm at the drinking water intake at Oakley, 10 to 20 ppm at the Antioch intake, and 20 to 50 ppm at the Carquinez Strait discharge (Figures G1-20a and G1-20b). These incremental changes are less than 1 percent of existing TDS concentrations. The area with incremental changes between 35 and 40 ppm is restricted to the Carquinez Strait area (lower plot on Figure G1-20c).

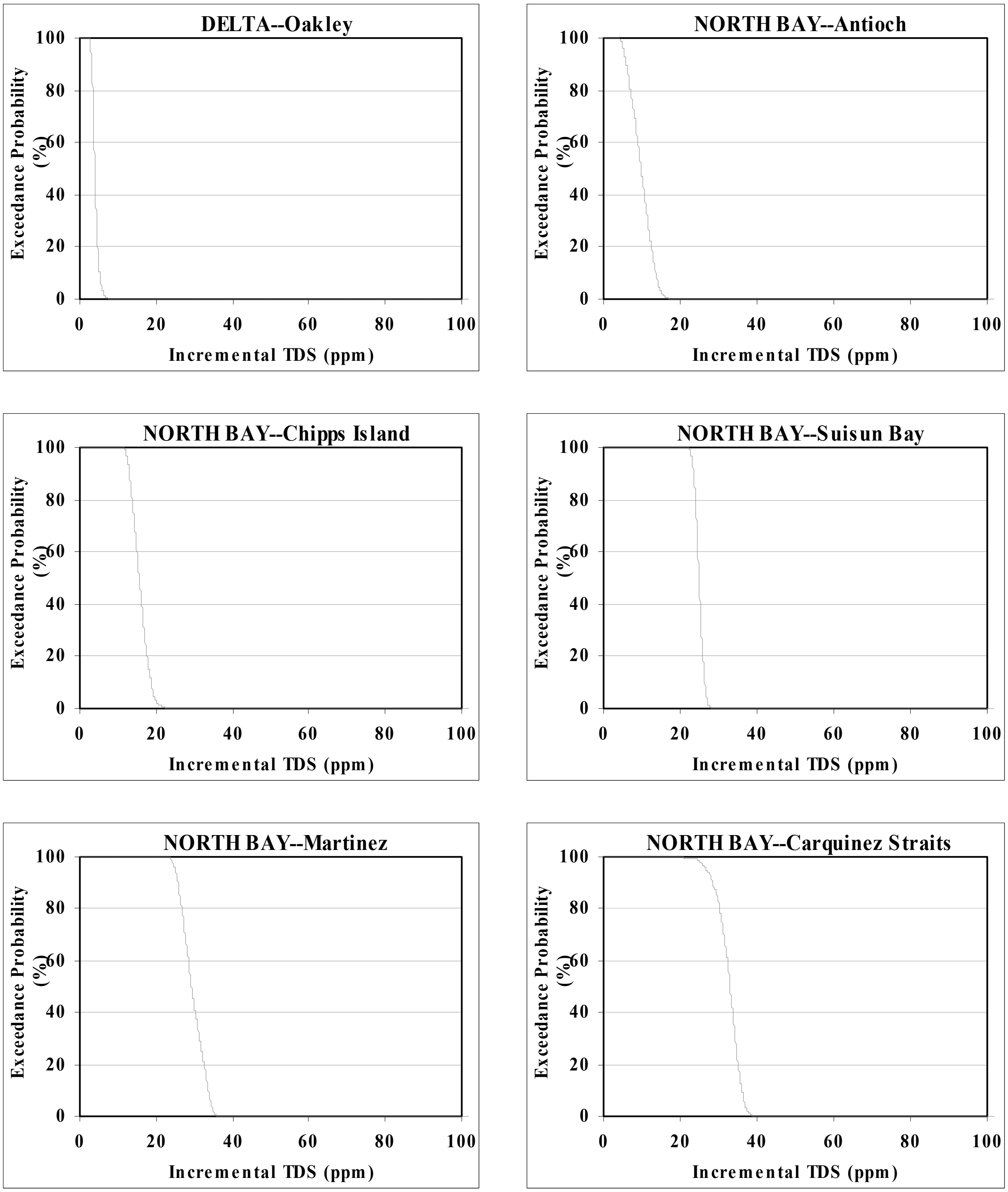
Changes in Selenium Concentrations. Increases in total Se concentrations due to the project are not predicted to cause exceedance of the 5 μg/L water quality objective (upper plot on Figure G1-21); however, increases in either dissolved concentrations or concentration adsorbed to suspended or benthic particulate matter may enhance bioaccumulation to marine organisms. Consequently, changes are expressed in this section relative to the dissolved and adsorbed parameters.

Predicted dissolved concentrations at the six time-series monitoring stations shown on Figure G1-14 are generally between 0.1 and 0.25 μg/L (dark lines on Figure G1-22a). The exception is in the immediate vicinity of the discharge at Carquinez Strait, where concentrations are typically between 0.2 and 0.3 μg/L. Although increases in dissolved concentration are less than 0.01 μg/L at the easternmost Jersey Point station, they are as high as 0.13 μg/L near the Carquinez Strait discharge (light lines on the figure). The probability of dissolved concentrations exceeding 0.2 μg/L at this station consequently increase from <2 to 14 percent (Figure G1-22b). As illustrated by the upper plot on Figure G1-22c, the area affected by the discharge is elongated from Carquinez Strait in the direction of the Pacific Ocean, with increases between 0.1 and 0.15 μg/L near the main channel of San Pablo Bay (lower plot on Figure G1-22c).

Predicted adsorbed Se concentrations on suspended sediment are generally between 0.4 and 0.6 mg/kg near the Delta, 0.4 to 0.8 mg/kg near Carquinez Strait, and 0.6 to 0.8 mg/kg in San Pablo and Central bays (dark lines on Figure G1-23a). Although increases in adsorbed concentration are less than 0.02 mg/kg at the easternmost Jersey Point station, they are as high as 0.4 μg/L near the Carquinez Strait discharge (light lines on the figure). The probability of adsorbed concentrations exceeding 0.5 μg/L at this station increase from 7 to 17 percent (Figure G1-23b). Similar to dissolved Se, the area affected by the discharge is elongated from Carquinez Strait in the direction of the Pacific Ocean boundary (top plot on Figure G1-23c), causing increases between 0.35 and 0.45 mg/kg to occur near the main channel of San Pablo Bay (bottom plot on Figure G1-23c).



URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Carquinez Discharge (July-Dec 1977) Total Dissolved Solids Concentrations Expressed as Incremental Change from Existing Conditions	FIGURE G1-20a



URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Carquinez Discharge (July-Dec 1977) Probability of Exceedance of Total Dissolved Solids Conc.–Existing and Project Conditions	FIGURE G1-20b

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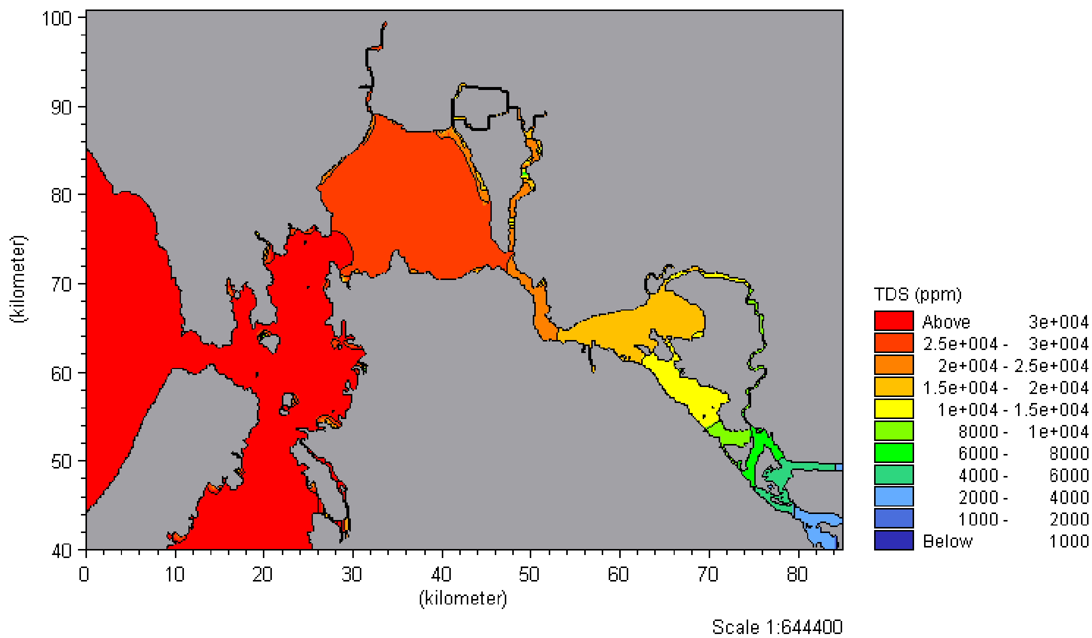
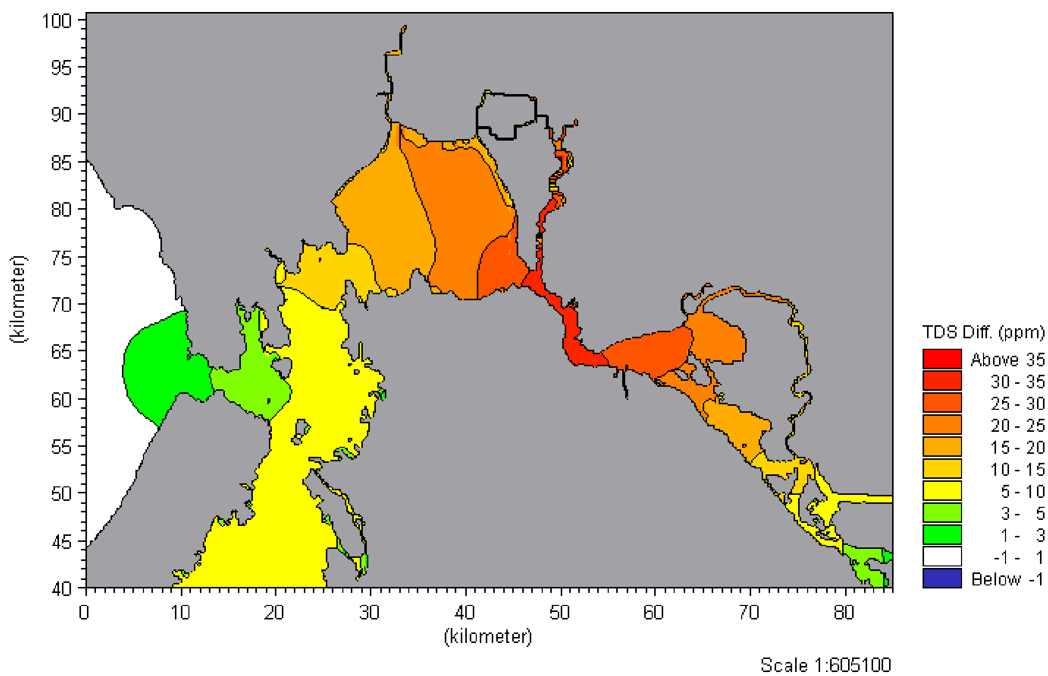
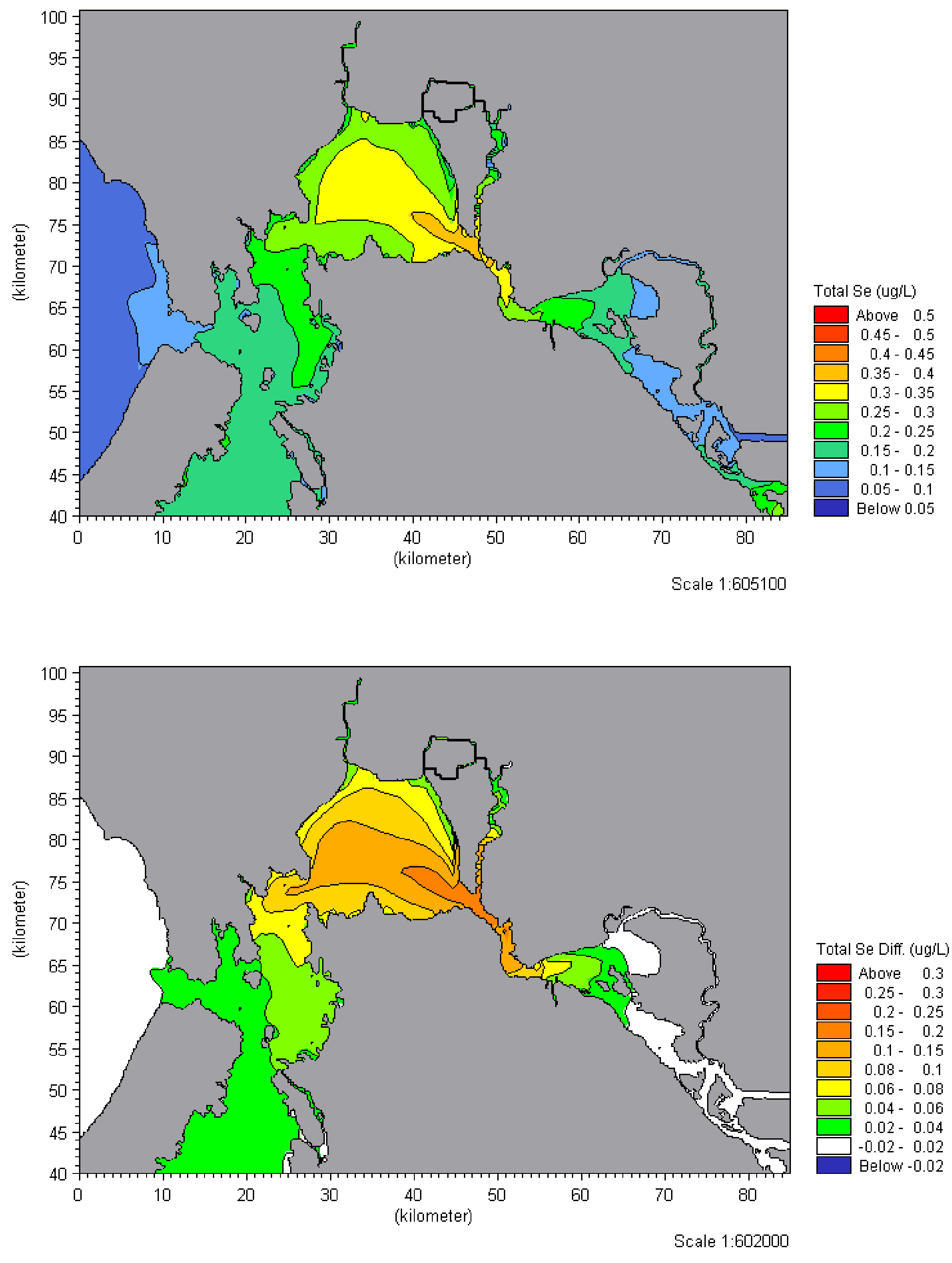
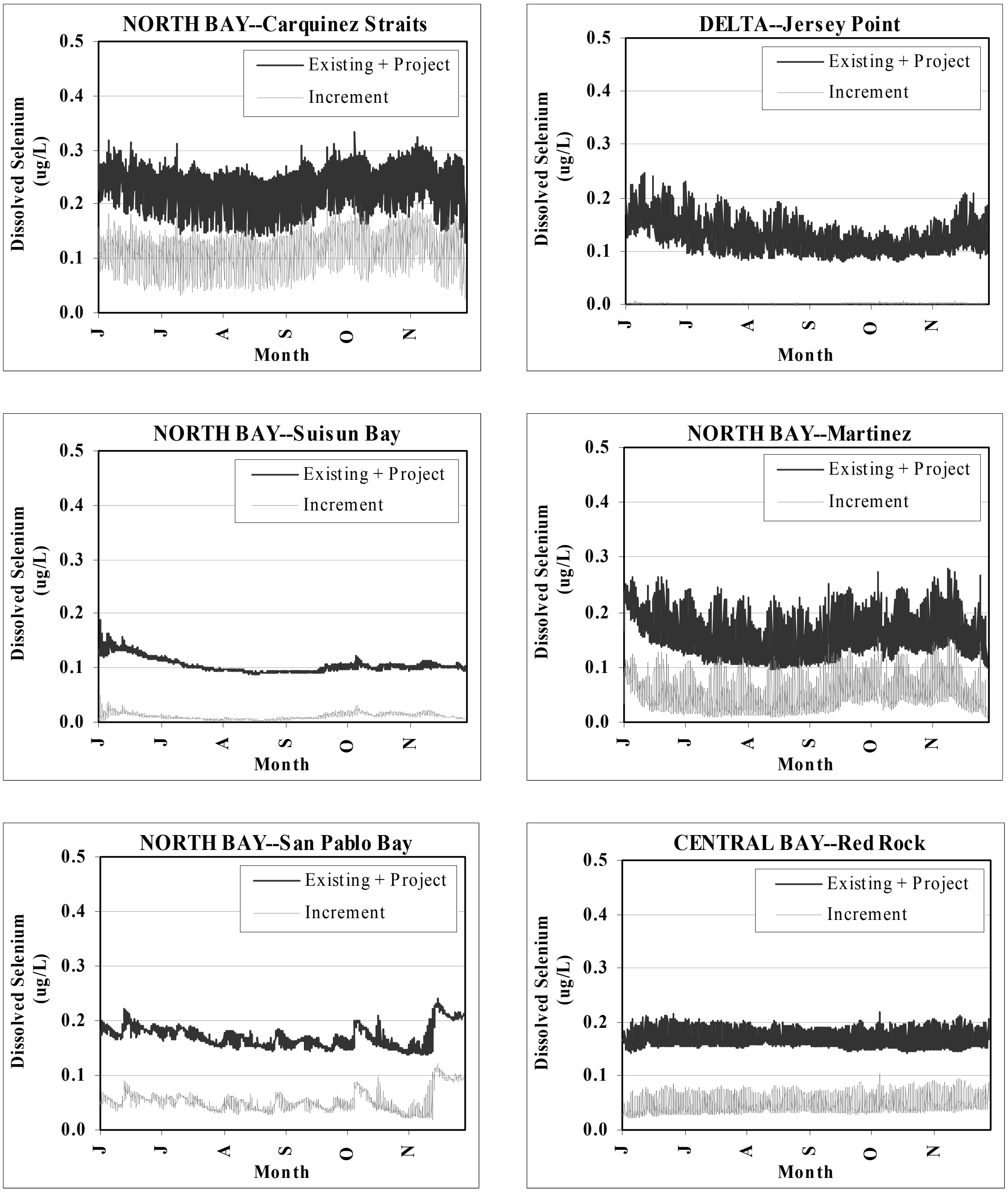




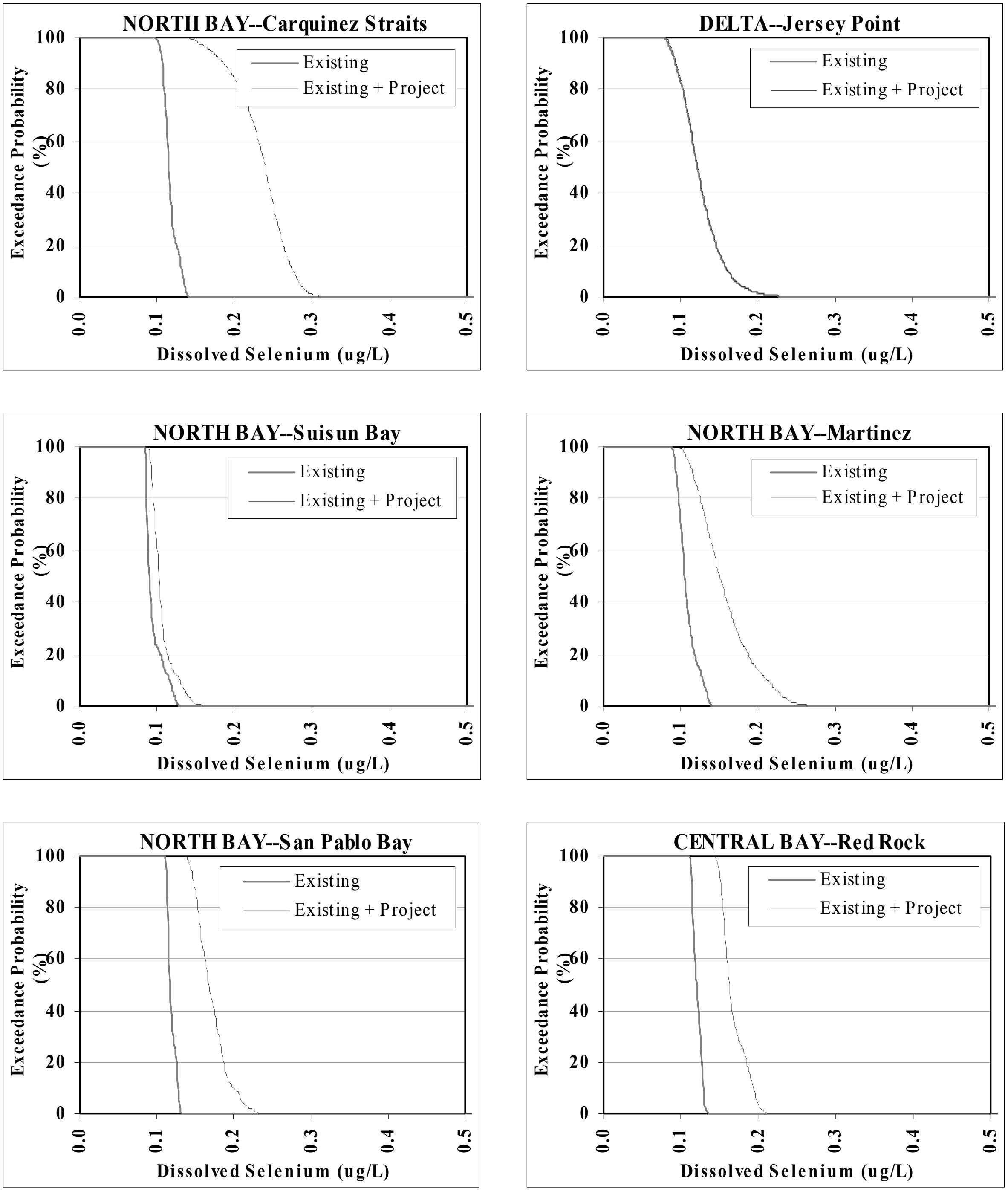
URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Carquinez Discharge (July-Dec 1977) Mean Total Dissolved Solids Concentration (TOP) Difference from Existing Conditions (BOTTOM)	FIGURE G1-20c



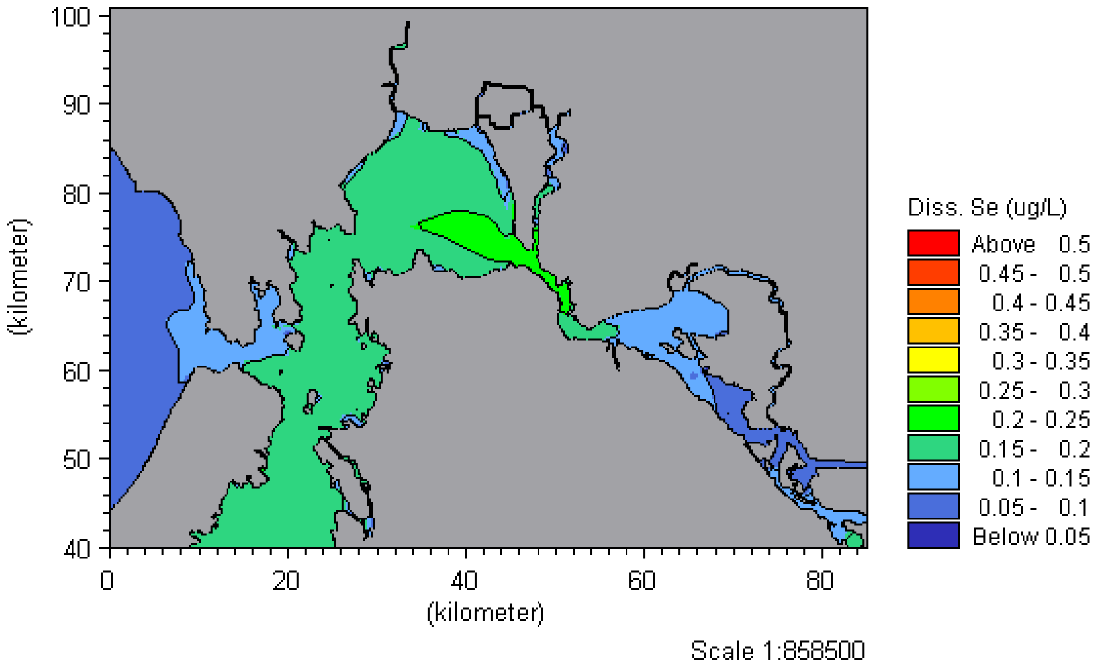
URS	17324004	MIKE 21 Carquinez Discharge (July-November 1997) Mean Total Selenium Concentration (TOP) Difference from Existing Conditions (BOTTOM)	FIGURE G1-21
	San Luis Drainage Feature Re-evaluation		

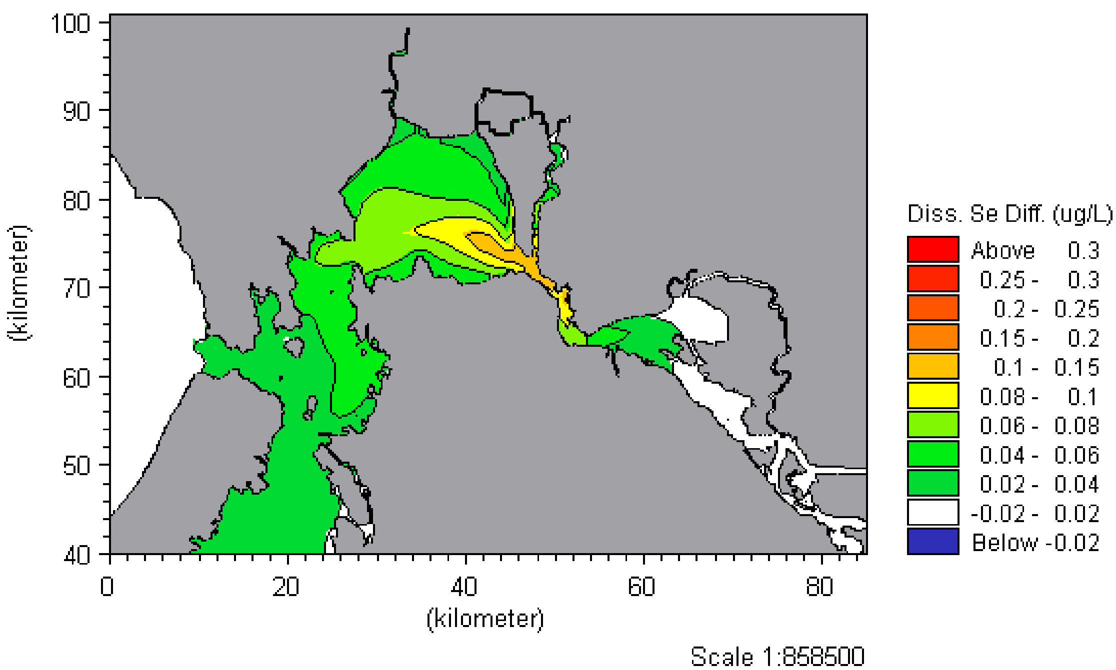


URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Carquinez Discharge (June-November 1997) Dissolved Selenium Concentrations Due to Project and Incremental Change from Existing Conditions	FIGURE G1-22a

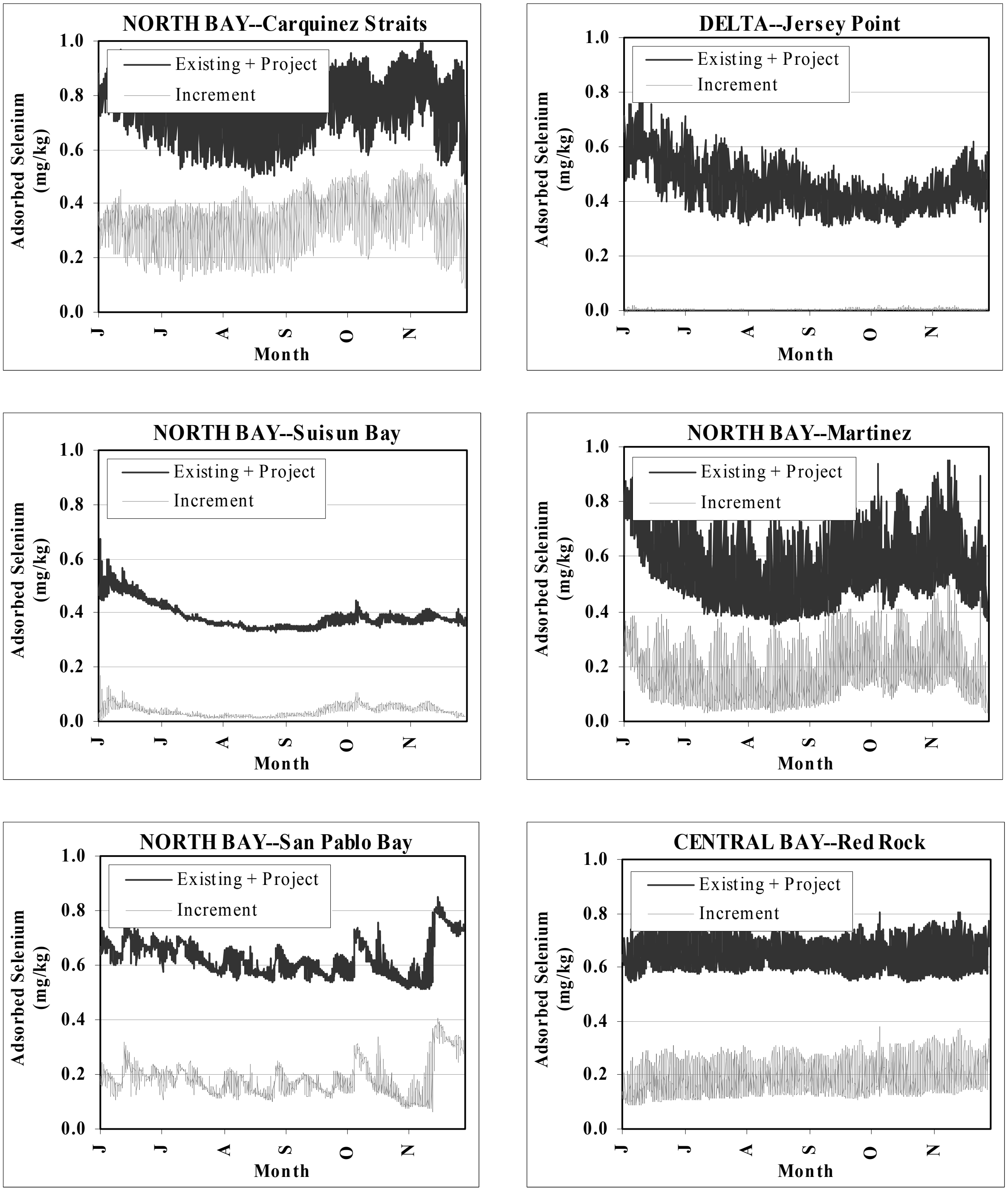


URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Carquinez Discharge (June-November 1997) Probability of Exceedance of Dissolved Selenium Concentrations–Existing and Project Conditions	FIGURE G1-22b

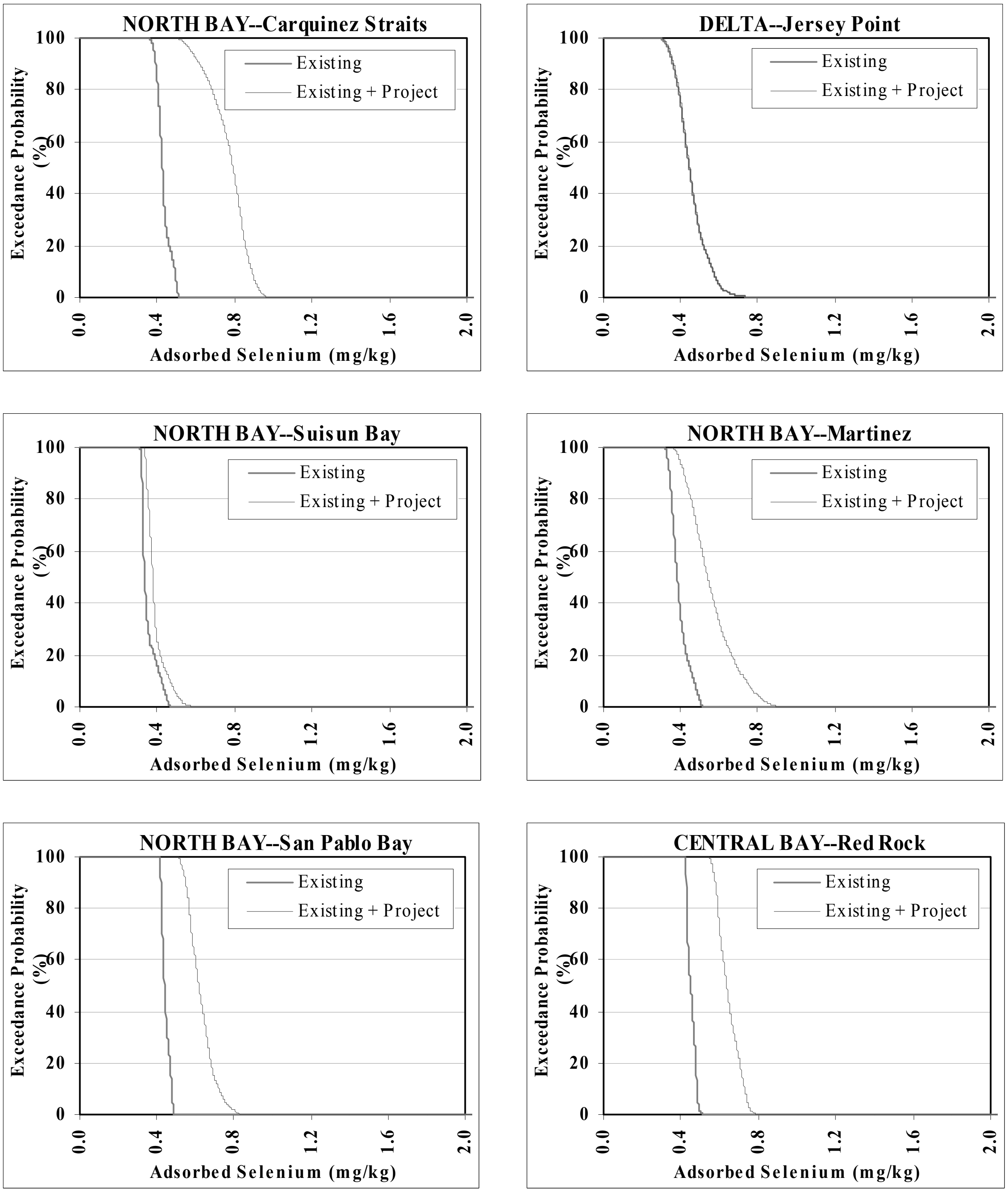




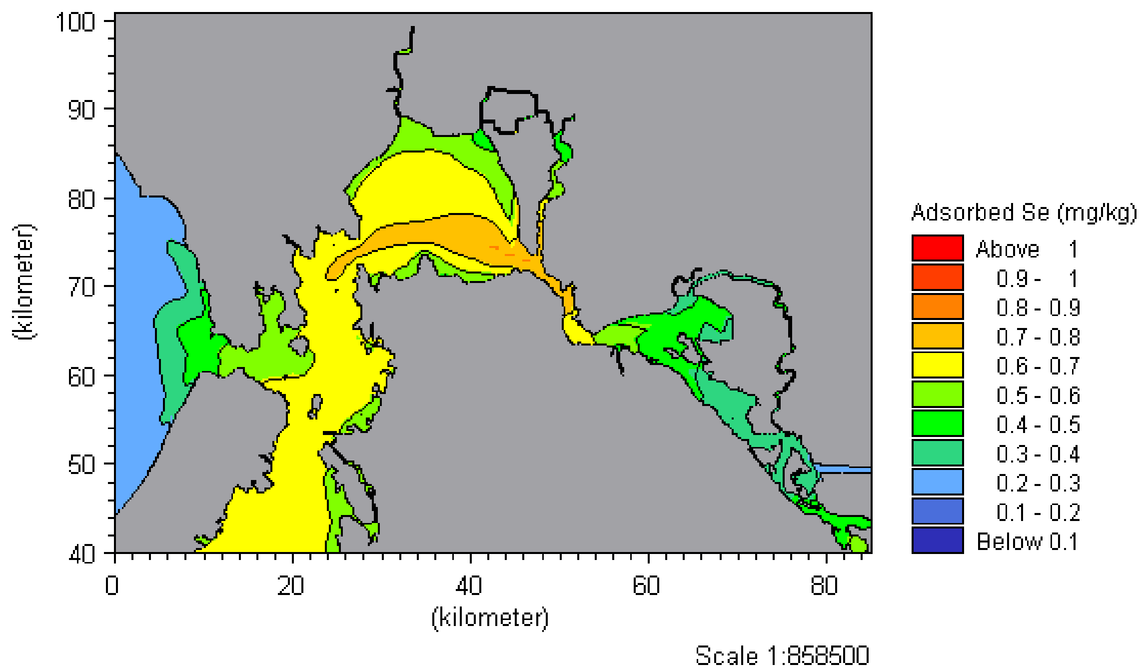
URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Carquinez Discharge (June-November 1997) Mean Dissolved Selenium Concentration (TOP) Difference from Existing Conditions (BOTTOM)	FIGURE G1-22c

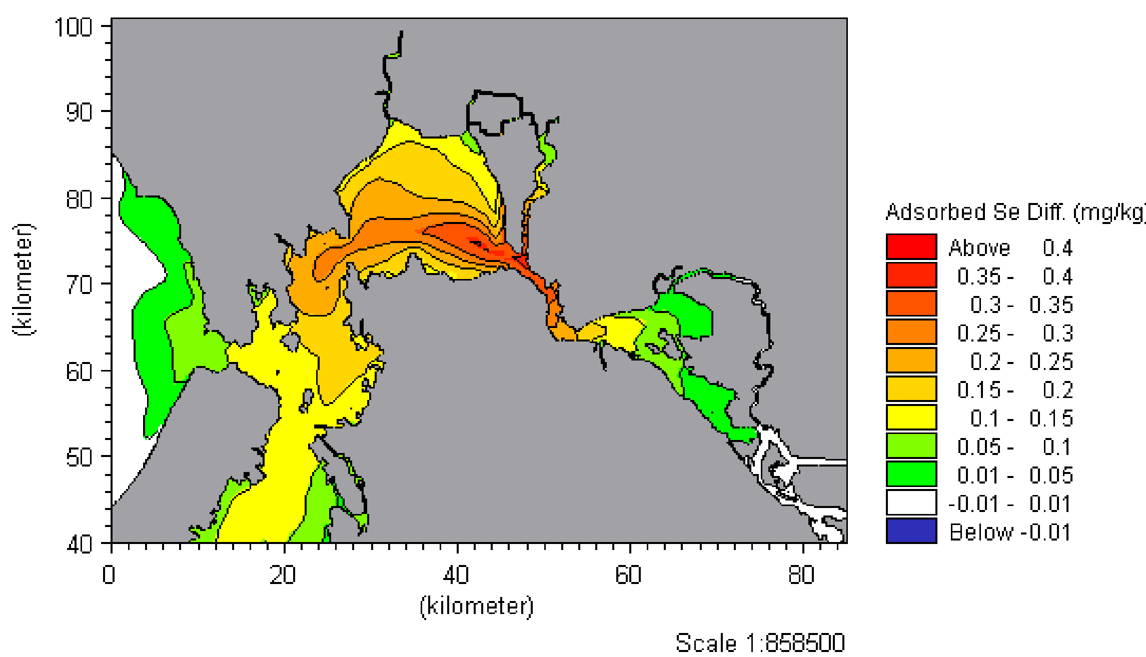


URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Carquinez Discharge (June-November 1997) Adsorbed Selenium Concentrations Due to Project and Incremental Change from Existing Conditions	FIGURE G1-23a



URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Carquinez Discharge (June-November 1997) Probability of Exceedance of Adsorbed Selenium Concentrations–Existing and Project Conditions	FIGURE G1-23b





URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Carquinez Discharge (June-November 1997) Mean Adsorbed Selenium Concentration (TOP) Difference from Existing Conditions (BOTTOM)	FIGURE G1-23c

Predicted adsorbed Se concentrations on benthic sediment are generally between 0.2 and 0.4 mg/kg near the Delta, 0.4 to 0.6 mg/kg near Carquinez Strait, and 0.4 to 0.8 mg/kg in San Pablo and Central bays (dark curves on Figure G1-24a). Part of the explanation for the lower concentrations near the Delta is that the majority of sediment transported and ultimately deposited near there is from the Sacramento River (with an average adsorbed concentration on suspended sediment of 0.2 mg/kg). Similarly, most of the increase above 0.5 mg/kg near Carquinez Strait is a direct consequence of the San Luis Drain discharge (compare dark and light lines on Figure G1-24a). Finally, the high Se concentrations on benthic sediment in the Central Bay is possibly an model artifact, where the effect of sand on the total benthic concentration cannot be included. As illustrated on Figures G1-24b and G1-24c (lower plot), an incremental increase occurs in the benthic Se concentration between 0.05 and 0.1 mg/kg.

Summary of Impacts on Drinking Water Intakes. Based on numerical modeling at a flow of 41 cfs of drainwater to the Delta at Carquinez Strait, this alternative provides a negligible increase in the total estuary flow of salts and concentrations at the Rock Slough and Old River intakes. Se concentrations are also well below the limits for drinking water.

G1.1.2.7 In-Valley Disposal Alternative

This alternative would contain the drainage and disposal service within the San Luis Unit. The components comprising this alternative include the installation of tile drains for drainage-impaired lands and a collection system to convey the drainwater to four agricultural reuse facilities located within the study area. At the reuse facilities drainwater would be used to irrigate salt-tolerant crops. Applying the drainwater at a rate of 4 acre-feet (AF)/acre would result in a 27 percent leaching rate. Approximately 73 percent of the original drainwater would be lost to evapotranspiration. Following reuse application, remaining drainwater would go through four treatment facilities.

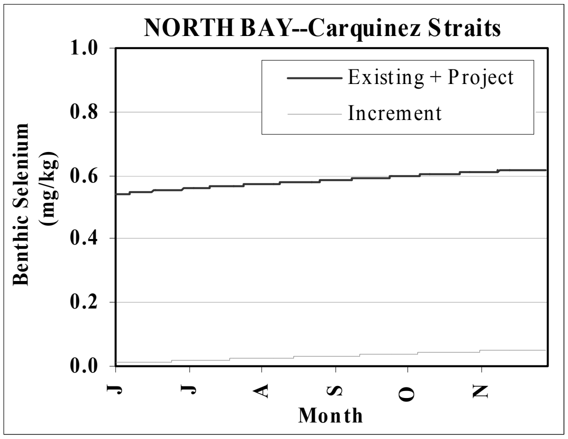
These facilities would consist of biological treatment reactors for Se removal and double-lined evaporation ponds to reduce the reused and treated drainwater to a dry salt. The residual dry salt would be permanently disposed of on site.

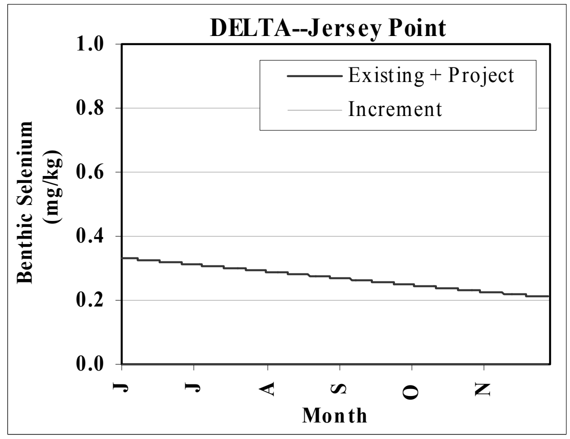
Construction Impacts

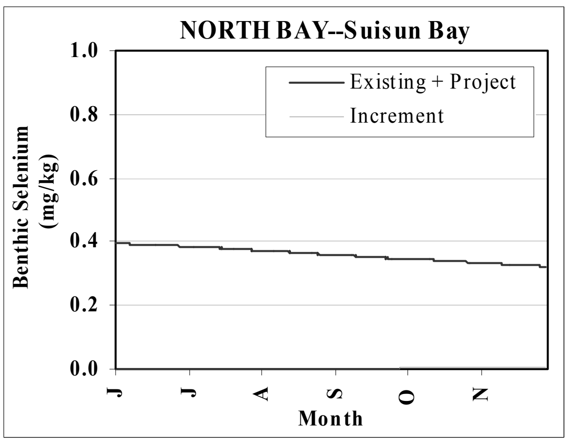
The construction impacts would be contained with the San Luis Unit. Construction impacts would be mainly limited to soil erosion and resultant turbidity of surface streams.

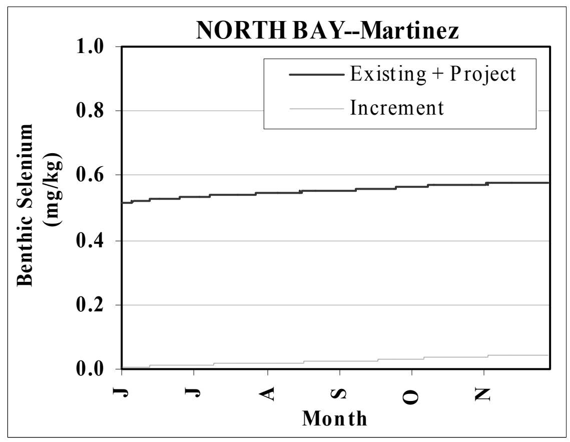
Operational Impacts

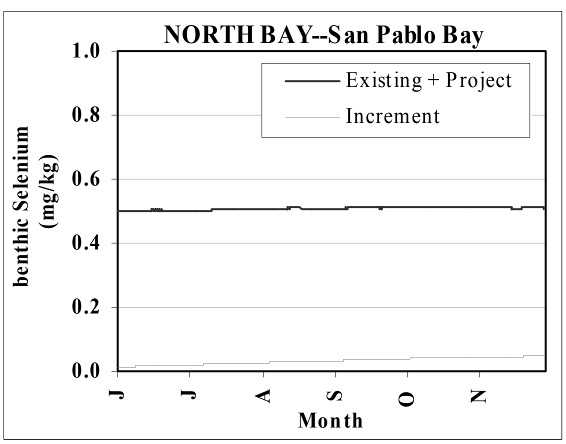
Due to the treatment facilities and the potential irrigation application rate the impacts to surface water would be minimal.

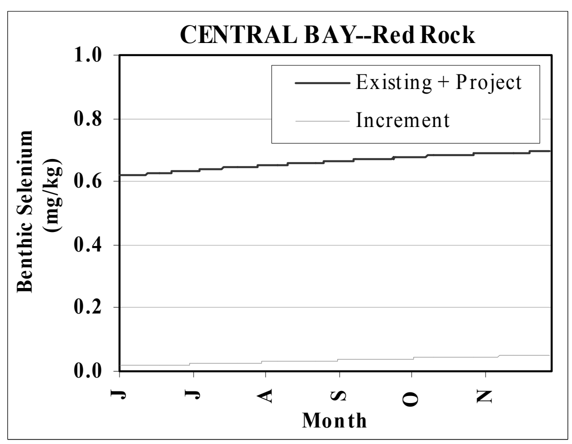




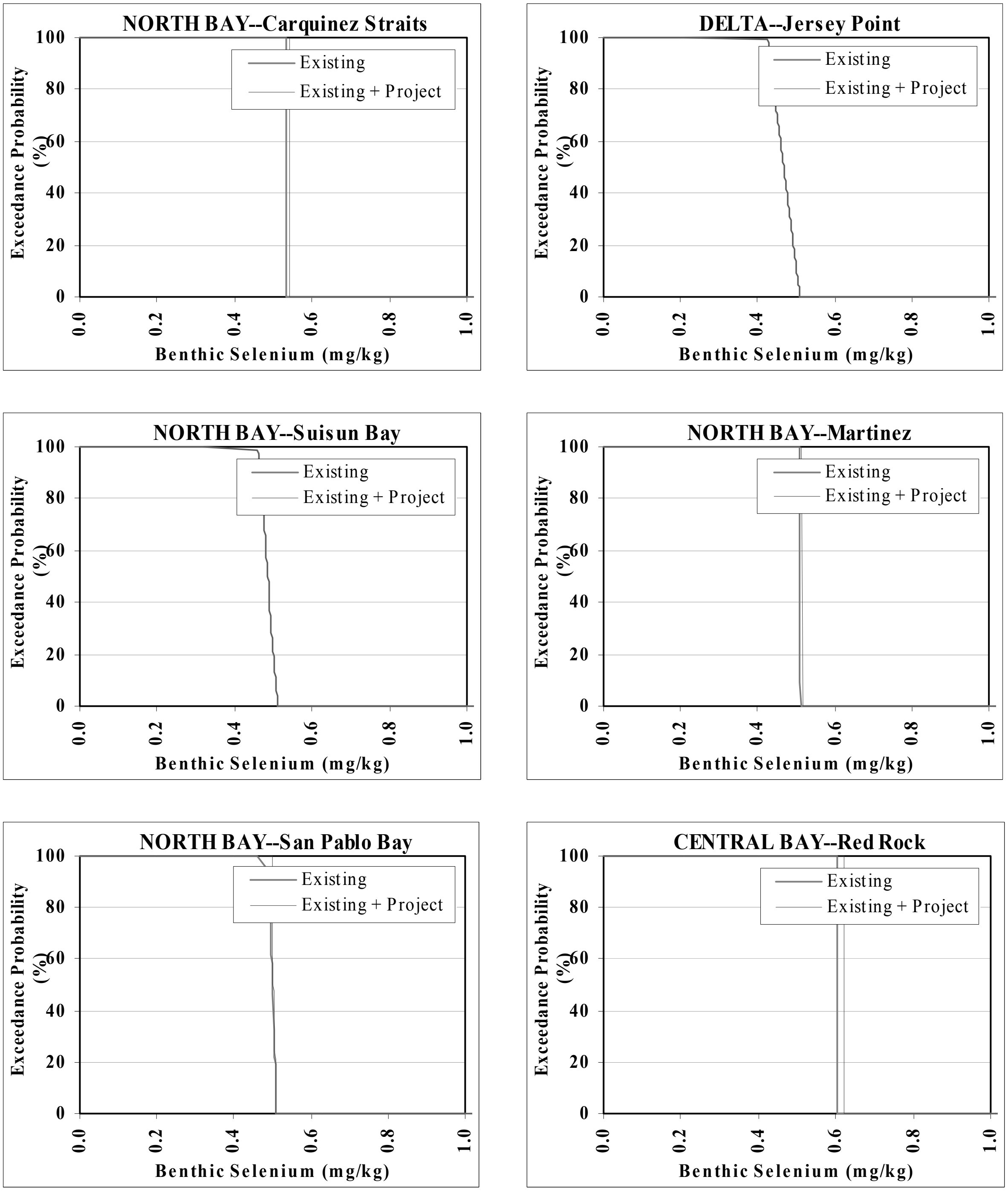








URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Carquinez Discharge (June-November 1997) Benthic Selenium Concentrations Due to Project and Incremental Change from Existing Conditions	FIGURE G1-24a



URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Carquinez Discharge (June-November 1997) Probability of Exceedance of Benthic Selenium Concentrations–Existing and Project Conditions	FIGURE G1-24b

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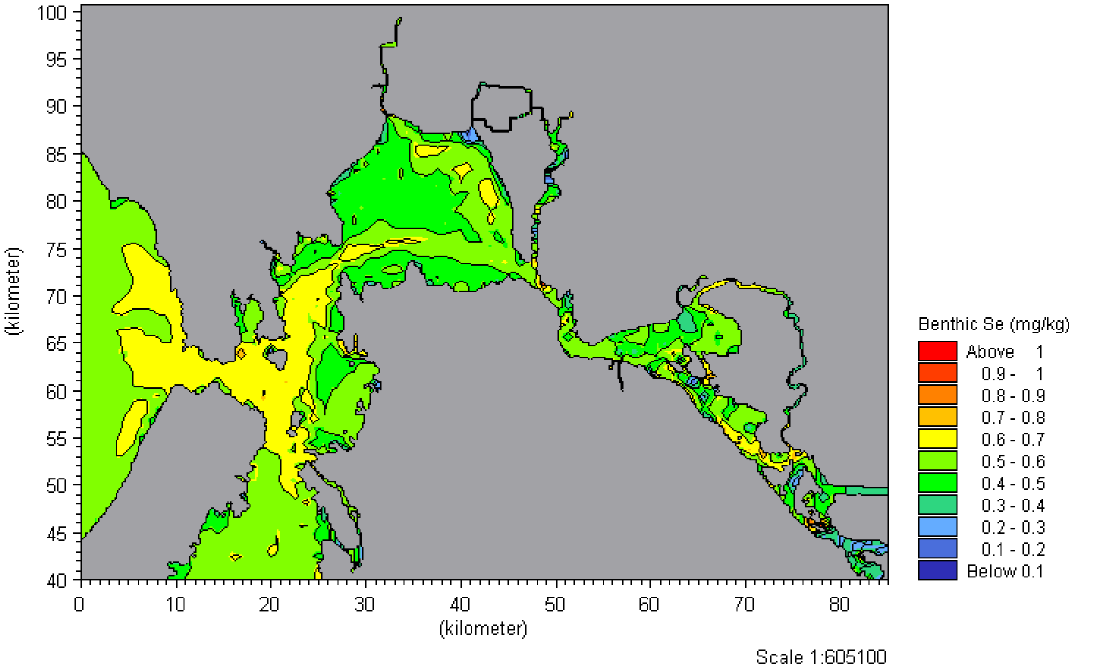
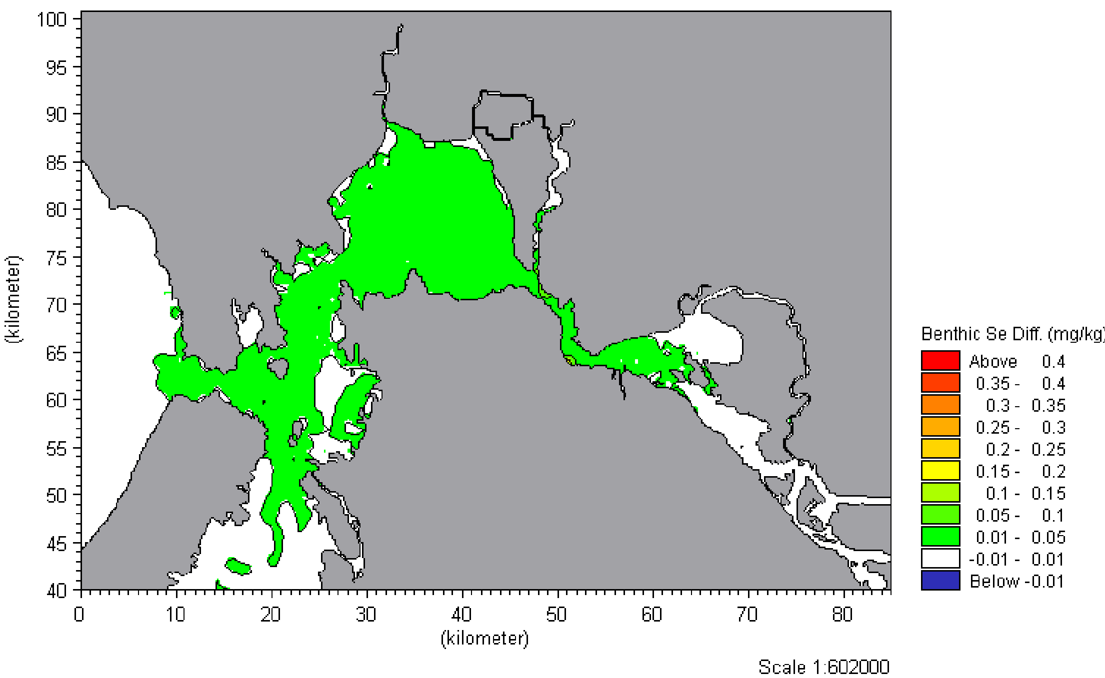




URS	17324004	MIKE 21 Carquinez Discharge (June-November 1997) Mean Benthic Selenium Concentration (TOP) Difference from Existing Conditions (BOTTOM)	FIGURE G1-24c
	San Luis Drainage Feature Re-evaluation		

G1.1.2.8 Modeling Results Summary

FDM-Predicted Changes in TDS Concentrations

For the Contra Costa intake at Rock Slough the simulation data show the probability that a 5 ppm TDS increment will be exceeded about 30 percent of the time. For the Contra Costa intake at Rock Slough the computed TDS concentration increment never exceeded 25 ppm. At Clifton Court Forebay the computed salinity increment exceeded 10 ppm less than 10 percent of the time.

MIKE 21-Predicted Changes in TDS Concentrations

During an extreme drought period such as 1977, average TDS concentrations at the drinking water intake at Oakley and Antioch are predicted to increase by 10 and 40 ppm due to a Chipps Island discharge (Table G1-12). For a Carquinez Strait discharge, incremental changes are predicted to be between 0 and 10 ppm, respectively. Given that average concentrations are between 3,000 and 7,000 ppm, the water during this period is unusable for drinking water even without the discharge.

Table G1-12
Mean Total Dissolved Solids Concentration (July–December 1977)

Station Name	Total Dissolved Solids (ppm)		
	Existing Conditions	Chipps Discharge Increment	Carquinez Discharge Increment
Oakley	3,380	10	0
Antioch	6,740	40	10
Chipps Island	10,290	50	20
Suisun Bay	15,780	40	20
Martinez	18,600	40	30
Carquinez Strait	23,600	20	30

MIKE 21-Predicted Changes in Selenium Concentrations

Incremental changes in dissolved Se are predicted to be between 0.1 and 0.2 μg/L at the discharge location (Table G1-13a). The area of increases in concentration greater than 0.1 μg/L is larger for the Chipps Island discharge due to the greater tidal flushing and dispersion that occurs near Carquinez Strait. Incremental changes in adsorbed concentrations in the vicinity of the Chipps Island and Carquinez Strait discharges are predicted to be 0.49 and 0.34 mg/kg, respectively (Table G1-13b), which approximately doubles the concentration at both locations. Incremental changes due to the Chipps Island discharge are spread over a larger area, which is similar to the trend found for dissolved Se. Finally, benthic Se concentrations are predicted to change the least on a relative basis (Table G1-13c); however, it is unclear from the time-series results that a steady-state concentration has been obtained after a 1-year simulation period. In no cases are the incremental changes described in this section of the report large enough to cause total concentrations to exceed water quality objectives.

Table G1-13a
Mean Dissolved Selenium Concentration (June–November)

Station Name	Dissolved Se (μg/L)		
	Existing Conditions	Chipps Discharge Increment	Carquinez Discharge Increment
Jersey Point	0.13	0.04	0.00
Chipps Island	0.09	0.18	----
Suisun Bay	0.09	0.12	0.01
Martinez	0.11	0.11	0.05
Carquinez Strait	0.12	----	0.12
San Pablo Bay	0.12	0.03	0.05
Red Rock	0.12	0.02	0.05

Table G1-13b
Mean Adsorbed Selenium Concentration (June-November)

Station Name	Adsorbed Se on Suspended Sediment (mg/kg)		
	Existing Conditions	Chipps Discharge Increment	Carquinez Discharge Increment
Jersey Point	0.46	0.14	0.00
Chipps Island	0.33	0.49	----
Suisun Bay	0.35	0.38	0.04
Martinez	0.39	0.38	0.17
Carquinez Strait	0.43	----	0.34
San Pablo Bay	0.44	0.09	0.18
Red Rock	0.45	0.10	0.19

Table G1-13c
Mean Adsorbed Selenium Concentration (June–November)

Station Name	Adsorbed Selenium on Benthic Sediment (mg/kg)		
	Existing Conditions	Chipps Discharge Increment	Carquinez Discharge Increment
Jersey Point	0.27	0.00	0.00
Chipps Island	0.71	0.15	----
Suisun Bay	0.36	0.03	0.00
Martinez	0.53	0.07	0.03
Carquinez Strait	0.55	----	0.03
San Pablo Bay	0.48	0.02	0.03
Red Rock	0.63	0.02	0.03

G1.2 BIOACCUMULATION ASSESSMENT

Bioaccumulation of Se by aquatic organisms is highly variable. Some factors that influence Se accumulation include chemical forms of Se present, water temperature, age of organism, organ or tissue specificity, and mode of exposure (Eisler 1985). In San Francisco Bay, one of the primary mechanisms of entry into the food chain is through assimilation by phytoplankton. Different algal species accumulate Se to varying degrees and in such a way that selenite and organic selenides are taken up in higher concentrations than selenate (Baines, Fisher, and Stewart

2002). Bivalves represent a significant source of dietary Se for wildlife in comparison to other benthic invertebrates and have also been shown to preferentially bioaccumulate selenite over selenate (Eisler 1985). Therefore, species composition of phytoplankton and benthic invertebrate communities are expected to have a high influence on Se accumulation and transfer through the food chain. Dietary preference, foraging strategy, and feeding rate significantly influence the rate of bioaccumulation in the food chain, which may ultimately lead to adverse effects in wildlife species (Luoma et al. 1992).

Once Se enters the aquatic environment, it has the potential to bioaccumulate in primary and secondary consumers (e.g., zooplankton, benthic invertebrates), and biomagnify as it reaches top-level predators (e.g., predatory fish, birds and mammals). Biomagnification is a form of bioaccumulation in which the concentration of a chemical in a higher-trophic-level organism is greater than the concentration in the food that this organism consumes. This phenomenon has been observed to result in a two- to six-fold increase in Se concentrations between primary producers and forage fish (Lemly 1999).

G1.2.1 Selenium Speciation and Bioavailability in Aquatic Systems

Se can exist in several oxidation states (IV, VI, 0, -II) as well as in organic and inorganic form. The reduced organic, elemental, or selenite forms of inorganic Se are converted to the selenite or selenate forms through the oxidation process. Methylation is the process by which inorganic or organic Se is converted to an organic form that contains one or more methyl groups (usually resulting in a volatile form). Assimilative reduction is the process in which oxidized forms are taken into cells and reduced to organic species such as seleno-methionine and seleno-cysteine. These organo-Se forms can then be released to the water column following death or depuration.

Four oxidation and methylation processes regulate the bioavailability of Se in aquatic systems:

- Oxidation and methylation of inorganic and organic Se by plant roots and microorganisms
- Biological mixing and associated oxidation of sediments that results from burrowing of benthic invertebrates and foraging activities of wildlife
- Physical agitation and chemical oxidation associated with water circulation and mixing (e.g., tide cycle, wind, current, stratification)
- Oxidation of sediments through plant photosynthesis (Lemly 1999)

These processes are responsible for converting relatively nonbioavailable inorganic forms of Se to highly bioavailable organic forms. Se can exist as a dissolved species, or can be attached to suspended particulate matter (SPM) in the water column, or to bedded sediment and detritus. The following oxidations states can occur in the dissolved phase:

- Selenide or organo-Se (-II), substituting for S (-II) in proteins seleno-methionine, or seleno-cysteine
- Selenite, SeO_3^{-2} (IV), an analog to sulfite
- Selenate (VI), an analog to sulfate
- Elemental Se, which has low solubility although it may exist as a suspended colloidal species

Differences in speciation, transformation to particulate forms, speciation on particulates, and accumulation rates in invertebrates all influence the level of bioavailability and bioaccumulation of Se in the food chain (Luoma and Presser 2000).

Se speciation and fate in the Bay-Delta Estuary are not well established; however, several studies have investigated the matter. Cutter (1989) measured and analyzed several species of Se in the Bay, Delta, and San Joaquin and Sacramento rivers between 1984 and 1987. The study measured total dissolved Se, selenate, and selenite. Concentrations of elemental Se plus selenide (-II + 0) were calculated from the measured data. Total dissolved Se concentrations were higher in the San Joaquin River than in the Sacramento River. However, because of diversions in the San Joaquin River, its flow only reached the Delta during April and May 1986. Selenate was the dominant dissolved Se species in the San Joaquin River (74±13%) while dissolved Se in Sacramento River was evenly split between selenate (48±15%) and elemental Se plus selenide (-II + 0) (40±15%). Further analysis revealed that higher concentrations of total dissolved Se and selenate were correlated with higher flows from the rivers to the Delta, implying that higher selenate and total dissolved Se concentrations are expected during winter months. Contrary to total dissolved Se and selenate concentrations, higher Se (-II and 0) concentration was found to be correlated with decreased flows. No correlation was found between flow and selenite (Cutter 1989). In the North Bay, industrial effluent discharges near Carquinez Strait were found to be significant sources of anthropogenic Se, particularly during the dry season when river discharges are low (Cutter 1989).

Another study of Se speciation in San Francisco Bay (Cutter et al. 1990) analyzed Se measurements from October (low flow) and December 1987 (high flow) and arrived at similar conclusions. The study found that the primary Se loadings to the Bay were Delta flows, industrial effluent near Carquinez Strait, and municipal discharges in the South Bay. The highest riverine loading of Se to the Bay occurred at times of high river discharge. Anthropogenic sources were relatively constant and, therefore, become more significant during the dry season when river discharge was small. Industrial discharges near Carquinez Strait contained up to three orders of magnitude more total dissolved Se than river discharges and, unlike river discharges, were dominated by selenite (62 percent of total dissolved Se) (Cutter et al. 1990). While the municipal discharges in the South Bay were higher in total Se than river discharges, the speciation of Se was similar (60 percent selenate, 25 percent selenite, 15 percent selenide + elemental Se) (Cutter et al. 1990).

More recent data presented by Cutter et al. (2000) indicated that while total Se concentrations have not increased since the mid 1980s, the percentage of selenite has diminished substantially, perhaps due to changes in industrial effluents. Particulate Se concentrations ranged from 0.2 to 1.1 micrograms per gram with the highest concentrations seen in the Delta and more than 75 percent of particulate Se was the most bioavailable form, organic selenide. Sedimentary Se was dominated by the elemental species, making it less bioavailable than the Se suspended in the water column (Cutter et al. 2000).

Approximately 90 percent of the Se present in drainwater is found as the selenate form. Prior to discharge to the Bay-Delta a biological treatment process would be used to remove approximately 80 percent of the Se from solution. It is not known what forms of Se would be discharged after treatment. Recent data from pilot Se treatment plants indicates a mix of Se species can be found in the effluent with approximately equal percentages of the total Se found as selenate and selenite, and organic species (Amweg and Weston, 2002 [in press]). The potential treatment system includes several additional treatment processes not used in the pilot plant that could affect the Se speciation.

G1.2.2 Primary Exposure Mechanisms

Since many environmental factors can have a significant impact on the mechanism by which waterborne Se is transferred to wildlife, concentrations of dissolved Se measured in surface water are often not useful for predicting exposure to upper trophic levels. For example, uptake of selenite from solution was too slow to account for the high tissue residues measured in clams (*Macoma balthica*) and Mediterranean mussels (*Mytilus galloprovincialis*) (Luoma et al. 1992). In fact, the uptake rate of dissolved selenite was responsible for less than 5 percent of the tissue residues of Se measured in clams. When Se is absent in surface water but present in sediment, it can still be transferred through the food chain. Se uptake by rooted plants and benthic invertebrates are two primary pathways that facilitate Se movement through the food chain. Long-term cycling of potentially toxic Se concentrations is highly dependent upon these pathways. Ingestion of rooted plants and benthic invertebrates often represents a source of continuous exposure to fish and wildlife, even when surface water is characterized by very low Se concentrations (Lemly 1999).

Some studies have generated data that show a statistical correlation between Se concentrations in surface water and biota. For example, a study on evaporation ponds in the Tulare Lake basin provided evidence to suggest that Se in water was a better indicator of Se in eggs of black-necked stilt (*Himantopus mexicanus*) than was Se in sediment (Hamilton and Lemly 1999). Based on the available literature, however, estimation of Se uptake through measured concentrations in sediment or surface water alone are not good predictors of bioaccumulation, as dietary exposure is usually responsible for the largest proportion of Se accumulation (Luoma and Presser 2000).

G1.2.3 Bioaccumulation in the Aquatic Food Web

Species that experience the highest level of chemical exposure are those most likely to suffer adverse effects, potentially at the population level. Due to the biomagnification potential of Se, species at the highest risk of toxicology effects are those found at the top of the food chain. In the *Selenium Verification Study* (Urquhart and Regalado 1991) the highest concentrations of Se in aquatic organisms were found in white sturgeon, a long-lived benthic predator of the Bay-Delta. The highest Se concentrations in aquatic birds in the Bay-Delta were found in surf scoter from Suisun and San Pablo bays. A surf scoter’s diet is almost entirely comprised of benthic invertebrates, as opposed to other birds evaluated in the *Selenium Verification Study*, which include mallards, double-crested cormorants, American bitterns, northern shoveler, and scaups. The diets of these birds are comprised of higher proportions of plant material, aquatic insects, or fish.

Studies conducted in the Bay-Delta have shown that predators with the highest tissue residues of Se are those that consume benthic invertebrates, with a high proportion consisting of bivalves (Luoma and Presser 2000). Predatory fish that primarily feed on water-column species are likely to be less exposed and accumulate less Se in their tissues than dimersal fish that consume benthic invertebrates, especially bivalves. In addition, studies on rates of accumulation revealed higher

Se concentrations in smaller mussels and freshwater fish than larger individuals (i.e., older). The reverse was reported for marine mammals and fish (Eisler 1985).

Se accumulates in the organs of biological systems to differing degrees. Crustaceans usually accumulate the highest Se levels in their exoskeletons, while the visceral mass and gills of mollusks usually contain the highest levels. In marine shrimps that were exposed to Se through their diet, highest concentrations were observed in the viscera and exoskeleton, suggesting that ingested Se is readily transferred from internal to external tissues. Highest Se concentrations in fish were found in the liver, kidney, and gills. Similarly, the highest concentrations in birds and mammals are often found in the liver and kidneys. However, Se concentrations in the muscle tissue of Hawaiian coots (*Fulica americana alai*) have been detected at sufficiently elevated levels to warrant the posting of consumption advisories (Eisler 1985).

A bioaccumulation factor (BAF) is the ratio of the concentration in organism tissue to the concentration in the ambient water. A review of readily available BAFs demonstrates the variability in Se accumulation between and among different aquatic organisms:

- Plankton: 680 to 2,600
- Aquatic plants: 166 to 24,400
- Aquatic insects: 371 to 5,200
- Mollusks: 32,000
- Crustaceans: 2,100
- Fish: 6 to 35,675 (Peterson and Nebeker 1992; Eisler 1985).

Most of these BAFs were derived using freshwater species, as BAFs for marine organisms have been rarely reported in the literature.

G1.2.4 Assimilation Efficiencies And Elimination Rates

Assimilation efficiency is the proportion of nutrients absorbed by the gastrointestinal tract of an organism that is available for daily maintenance, growth, reproduction, and locomotion. Assimilation efficiencies for Se vary widely between and within the various species of aquatic organisms. Foraging strategies and dietary composition are the primary factors that influence the assimilation of Se. For example, a CALFED study conducted on bivalves in Grizzly Bay reported the highest assimilation efficiency of Se in the Asian clam (*Potamocorbula amurensis*), a suspension feeder found in high abundance in the Bay (Schlekat et al. 2000). Lower Se concentrations were detected in crustaceans (Baines, Fisher, and Stewart 2002). These data correspond to Se concentrations measured in fish species that consume these organisms. For example, tissue residues in sturgeon (which mainly consume clams) were much higher than in striped bass (which mainly consume crustaceans).

Luoma et al. (1992) studied the effects of Se exposure on another common bivalve in the Bay, the balthic clam (*Macoma balthica*). The balthic clam is a deposit feeder with suspension feeding capabilities. Like the Asian clam, the balthic clam primarily consumes benthic and suspended microorganisms (diatoms) and detritus. The results of this study showed that organic Se present in diatoms was retained much more efficiently than elemental Se. Additionally, the average absorption efficiency of organic Se was 86 percent, which indicates that Se is persistent in the digestive tract of bivalves following consumption of microorgansisms. Little information is available on the detrital pathway, although Se uptake via this pathway is expected to be less efficient than uptake from living plant material (Luoma and Presser 2000). The assimilation efficiency of elemental Se in nonliving particulate material was reported at 22 percent (Luoma et al. 1992).

The predominant form of Se in oxidized surface water is predicted to be selenate. Selenate can be converted to less soluble forms such as selenite and elemental Se in reducing conditions. Although elemental Se may be immobilized in sediments and assimilated by some bivalves, assimilation of Se in this form is less efficient than organic Se (Luoma et al. 1992).

Elimination rates for Se also vary among aquatic organisms and are another major determinant of the time required for and the magnitude of bioaccumulation. The time for 50 percent excretion of accumulated Se has ranged from 13 to 181 days in various species of marine and freshwater fauna. Time for 50 percent excretion in 30-day elimination trials was approximately 15 days from the gills and erythrocytes (i.e., red blood cells); however, essentially no elimination occurred from the spleen, liver, kidney, or muscle. Studies on crustaceans have revealed higher Se concentrations in fecal pellets than in the actual diet. Therefore, fecal pellets may represent a possible biological mechanism for downward vertical transport of Se in marine and freshwater environments (Eisler 1985).

Experiments suggest that Se concentrations in fish tissue resulting from dietary uptake do not reach equilibrium until at least 90 days of constant exposure (Reclamation 2001, Appendix E). Evaluation of water and tissue data collected in the Central Valley indicate that Se concentrations in fish tissue were best predicted using the average water concentration 1 to 7 months prior to collection of the fish sample. Se concentrations in aquatic invertebrate tissue were best predicted using the average water concentration 30 to 60 days prior to collection of the fish sample (Reclamation 2001).

G1.2.5 Toxicological Effects

Se is an essential element necessary for proper enzyme formation and function. Insufficient Se in the diet may have harmful and sometimes fatal consequences on terrestrial and aquatic organisms. However, chronic exposure to significantly elevated Se levels in the diet or water can also cause severe toxicological effects, including death. The concentration range separating effects of Se deficiency from those of toxicity (i.e., selenosis) is very narrow (Luoma and Presser 2000). With the exception of mortality, the two major toxicological impacts to aquatic organisms from chronic exposure are reproductive effects and teratogenesis (i.e, malformations in developing fetus). Excessive Se contamination is often attributable to localized extinction of certain species and reduction in biodiversity.

Based on field and laboratory studies with fish and wildlife, it is apparent that elevated Se concentrations in environmental media, including dietary components, can cause reproductive abnormalities. These abnormalities include congenital malformations, selective bioaccumulation by the organism, and growth retardation (Eisler 1985).

G1.2.5.1 Fish and Aquatic Organisms

Toxicological effects observed in marine and freshwater algae subsequent to Se exposure include growth inhibition and shifts in species composition. In protozoans, Se has been shown to cause swimming impairment by causing a reduction in the rate of locomotion. Physiological effects in fish exposed to Se have been well documented and include anemia, loss of equilibrium, swollen gills, lethargy, loss of coordination, muscle spasms, protruding eyes, swollen abdomen, liver degeneration, and kidney and heart damage (Eisler 1985). Reproductive impairment is also known to occur in fish, and these effects may result in ovary degeneration, reduced hatching success and embryo development, and inhibition of fry growth. Vulnerable stages in fish are egg, larvae, and fry because once external feeding begins, Se exposure will not cause further deformities (Luoma and Presser 2000). In some cases, fish embryos exposed to elevated Se concentrations in water during development hatched successfully, but the larvae died soon after hatching. Finally, Se has been shown to induce chromosomal aberrations in fish; however, these types of effects do not appear to be well documented (Eisler 1985).

G1.2.5.2 Birds and Mammals

Ingestion of Se in dietary items has been shown to cause congenital malformations in rodents and livestock. Generally, offspring of females chronically exposed to Se in their diet were emaciated and unable to nurse. In another study, mice given Se in drinking water reproduced normally for three generations, but had fewer and smaller litters. Pups were runts with high mortality before weaning, and most survivors were infertile (Eisler 1985).

Chronic effects of Se exposure in birds include decreased egg weight, reduced hatching success, embryo deformities, and offspring mortality. A significant portion of the Se consumed by birds is transferred to their offspring and can kill developing embryos in the egg or induce lethal or sublethal teratogenic deformities. Adults that experience dietary exposure may suffer complete reproductive failure without exhibiting clinical symptoms themselves (Lemly 1999).

G1.2.6 Bioaccumulation of Selenium in Bivalves of the Bay-Delta Estuary

G1.2.6.1 Existing Data

To model bioaccumulation throughout trophic levels in the affected area, a review was conducted on published data on Se concentrations in bivalve tissue, sediment, and water at various sampling locations in San Francisco Bay and the Delta. The RMP has been monitoring various stations throughout the greater Bay ecosystem several times a year since 1993 (SFEI 2002). Although the Mussel Watch program implemented by the National Oceanographic and Atmospheric Administration measured Se concentrations in mussels in the Bay before the RMP began, this program did not include measurements in sediment or water. To develop site-specific BAFs, it is necessary to obtain colocated samples in both tissue and water (or sediment) collected during the same time period. Because the RMP provides colocated water, sediment, and bivalve tissue data, these data sets have been used to evaluate correlations between environmental concentrations and tissue concentrations of Se in the Bay.

For this evaluation, various groupings of the RMP data were experimented with to identify the strongest correlations between Se concentrations in tissue versus Se concentrations in water and sediment. Correlation plots were run on data for individual sampling locations, grouped sampling locations, and the entire data sets. Correlation plots of Se concentration in tissue versus Se concentration in sediment, dissolved Se concentration in water, and total Se concentration in water did not display any significant trends. However, bivalve exposure to Se primarily occurs through filtering of particulate matter in their environment. Therefore, the dissolved Se concentration was subtracted from the total Se concentration in water (to estimate the Se concentration associated with the particulate phase), and this result was divided by the total suspended solids concentration to obtain the Se concentration on SPM. For each RMP North Bay and Delta station, this SPM Se concentration was plotted against measured bivalve tissue concentrations. In some cases, the SPM Se concentration was negative due to analytical error; these data points were excluded from the analysis. In addition, a data point from the Sacramento River station was excluded from analysis due to the fact that the tissue concentration recorded was anomalously high (4 times higher than the next largest value in the data set). Linear regressions were then applied.

Most sites (six of eight total) displayed the expected increasing bivalve tissue Se concentrations with increasing SPM Se concentrations. However, correlations were generally weak ($r^2 < 0.15$). The Point Pinole and Napa River mouth stations showed relatively strong correlations between SPM and tissue Se concentrations ($r^2 = 0.50$ and 0.52, respectively). The Petaluma River station data contained too few points to establish a correlation, but when grouped with the Napa River station (both stations are in the North Bay at the mouths of freshwater creeks) a better correlation between SPM and tissue Se concentrations than either station alone was observed ($r^2 = 0.53$). In the South Bay, the Coyote Creek station displayed a correlation as well ($r^2 = 0.62$).

The RMP deploys three different bivalve species due to varying salinities in different areas of the Bay. With the exception of the Point Pinole station, at which the mussel *Mydelis californicus* was deployed, all stations with acceptable correlations contained the oyster *Crassotrea gigas*. All data from the North Bay and Delta were also grouped and analyzed by species (*C. gigas, M. californicus*) or by location (rivers, open-water Bay-Delta); no significant correlations were observed. The third bivalve deployed in the RMP study was the clam *Corbicula fluminea*. Available Se tissue concentrations in *C. fluminea* deployed at the Sacramento River and Grizzly Bay stations displayed no significant correlations with SPM Se concentrations.

Many reasons are likely why the RMP data may not always exhibit good correlations between Se concentrations in corresponding water, sediment, and tissue samples. Some of the main factors are suspected to be the following.

The RMP sediment and water data consist of instantaneous point concentrations collected one to three times per year. Bivalves from uncontaminated waters are deployed at stations in the Bay for 90 days, after which they are sampled for Se and other trace elements. Sampling dates and station locations for water and bivalve tissue do not always match; therefore, the data set used for the correlations was not very large. In addition, the water quality at one point in time during a 3-month bivalve deployment period may not be representative of the average concentration over that 3-month period. If more frequent water analyses were conducted, temporally averaged concentrations could be calculated, and these average concentrations would most likely be a better predictor of concentrations in tissue.

As discussed earlier, bioaccumulation potential varies dramatically between different species of Se. No data are available on Se species present in the samples collected.

The deployment period may not correspond to a period of abundant phytoplankton food. Therefore, the bivalves may have very low ingestion rates during the deployment period, resulting in low assimilation of Se.

Bioaccumulation of Se may differ substantially between different species of bivalves. For example, Linville et al. (2002) found that Se concentrations in resident Asian clams collected at three RMP sampling locations were often 2 to 3 times higher than Se concentrations in the deployed bivalve species. Since the Asian clam was introduced to the Bay-Delta Estuary in 1986, it has rapidly invaded and displaced native species. As a result, it is likely that this clam now composes a large percentage of the prey of many upper trophic level receptors.

G1.2.6.2 Biota-Sediment Accumulation Factor

The RMP data were used to develop a Bay-wide biota-sediment accumulation factor (BSAF) based on the ratio of Se concentration in bivalve tissue to Se concentration on SPM. For development of the BSAF, the SPM concentration was selected over water or bedded sediment concentration because this was the only media for which a reasonable correlation with tissue concentrations was exhibited, as discussed above. In addition, the available data indicate that food-web uptake of Se is much more important than uptake of Se dissolved in the water column. Bivalves feed on both SPM in the water column and detrital matter in bedded sediment, depending on species and availability of food. Because the RMP data exhibited no good correlations between Se concentrations in bedded sediment and tissue, the BSAF developed with SPM data was used to predict tissue concentrations from both the SPM Se concentration and the bedded sediment Se concentration.

The initial goal was to identify separate BSAFs for several different regions of the Bay, based on habitat types and differences in Se speciation. However, because strong correlations were only exhibited at a few sampling locations throughout the Bay, not enough data were available to assign BSAFs to specific regions. Therefore, the BSAFs calculated for each of these locations were averaged to calculate a BSAF for the entire Bay-Delta Estuary.

The BSAF for each location was calculated as the unitless ratio of the average Se concentration in SPM (mg/kg dry weight) to the average Se concentration in bivalve tissue (mg/kg dry weight). Therefore, the Se concentration in SPM can be multiplied by the BSAF to predict the Se concentration in bivalve tissue. BSAFs were calculated based on concentrations in *C. gigas*, because the best correlations were observed for this species, as discussed above. BSAFs calculated for each location are summarized as follows:

- Napa River mouth BSAF = 4.5
- San Pablo Bay BSAF = 4.7
- Coyote Creek mouth BSAF = 3.4

The average of the above BSAFs is 4.2, and this number was used as the Bay-wide BSAF for this evaluation. This BSAF is similar to the predictions made by Luoma and Presser (2000), using a kinetic bioaccumulation model. They predicted that Se concentrations in bivalve tissue (mg/kg dry weight) would be 8 times greater than Se concentrations in particulate matter for organo-Se, the most bioavailable form, and 2 times greater for elemental Se, the least bioavailable form. The BSAF of 4.2 used for this evaluation falls in between these values, as would be expected.

M. californicus exhibited a fairly strong correlation at Point Pinole, and the BSAF calculated for this species at this location was very low (1.0). To determine whether the difference was likely to be due to differences in Se speciation and bioavailability at this location, the average ratio of *M. californicus* tissue concentration to SPM concentration for the entire RMP data set was compared to the average ratio for *C. gigas.* The average ratio for *M. californicus* was 0.63, while the average ratio for *C. gigas* was 4.0. Therefore, it is likely that the large difference is due to the difference in bivalve species. *M. californicus* is a detrital feeder on bottom sediments, while *C. gigas* is expected to obtain much of its food from particulate matter in the water column.

G1.2.6.3 Bioconcentration Factor

A bioconcentration factor (BCF) was also developed in order to predict how much Se is expected to be bioaccumulated directly from the water column. The BCF is the ratio of the average dissolved Se concentration in water (mg/L) to the average Se concentration in bivalve tissue (mg/kg dry weight). Therefore, the units of the BCF ratio are L/mg, and the concentration of dissolved Se in water can be multiplied by the BCF to obtain the Se concentration in tissue at a given location.

A literature search was conducted to obtain information on studies that investigated BCFs in various organisms. Although a substantial number of studies were identified, the vast majority of these studies were conducted on freshwater species. To compare uptake routes (Se absorbed to particulate matter versus dissolved in water), it was desirable to identify BCF studies conducted on estuarine bivalves similar to those used in the RMP monitoring. Two such studies were identified.

Zhang et al. (1990) conducted a laboratory experiment to investigate Se uptake in the clam *Puditapes philippnarum*. However, they measured Se concentrations in the shell and in the whole body (including the shell), but not in the soft tissue alone. Because the RPM measured Se concentrations in the soft tissue alone, it is not appropriate to compare the results of these studies.

A study by Fowler and Benayoun (1976) investigated uptake of selenite (IV) and selenate (VI) by the mussel *Mydelis galloprovincialis*. Groups of mussels were placed in water containing 1, 10, and 100 ppb of either form of Se, and during a period of 21 days, Se was allowed to accumulate. Selenite tended to accumulate almost an order of magnitude more than selenate. Absorbed Se appeared to vary approximately linearly with water concentration. Se concentrations in soft tissue were given on a wet-weight basis, and no information on moisture content was provided. To calculate a BCF that could be used to predict tissue concentrations on a dry-weight basis, it was necessary to assume a moisture content. The average moisture content of *M. californicus* (a similar species of mussel) measured by the RMP was 88 percent, and this value was used for conversion to dry weight. The average ratio of soft tissue Se concentration (mg/kg dry weight) to water selenite concentration (mg/L) was 1,750. This value was used as the Bay-wide BCF for this evaluation.

G1.2.6.4 Temporal and Spatial Averaging

Based on the water quality modeling results (see Section G1.1.2.2), the summer and fall months are expected to exhibit the highest Se concentrations. Therefore, the 6-month period of June–November was used to calculate temporal averages of Se concentrations in bivalves for each scenario (No Action Alternative, Delta-Chipps Island Disposal Alternative, and Delta-Carquinez Strait Disposal Alternative). A shorter time averaging period (1 to 3 months) was considered, but the water quality modeling results indicate that daily average Se concentrations do not fluctuate much during the 6-month period. Se concentrations in the water column do fluctuate during the tidal cycles, but bioaccumulation typically does not fluctuate on this short of a time scale.

Spatial averages of 6-month average Se concentrations in bivalve tissue were calculated for four regions of the Bay-Delta Estuary as shown on Figure G1-25: the Delta, San Pablo Bay, Central Bay, and South Bay.

G1.2.7 Bioaccumulation Model Results

Predicted 6-month average bivalve tissue concentrations throughout the Bay-Delta Estuary for each of the three scenarios are presented on Figures G1-26, G1-27a, G1-27b, G1-28, G1-29a, and G1-29b. In addition to predicted concentrations, the incremental change from No Action Alternative conditions is also shown for each of the Delta Disposal Alternatives. Predicted spatial averages of 6-month average Se concentrations in bivalve tissue are presented in Tables G1-14, G1-15, and G1-16. Predictions for all scenarios are shown based on bioconcentration from Se dissolved in water, bioaccumulation from Se adsorbed to SPM, and bioaccumulation from Se adsorbed to benthic sediments.

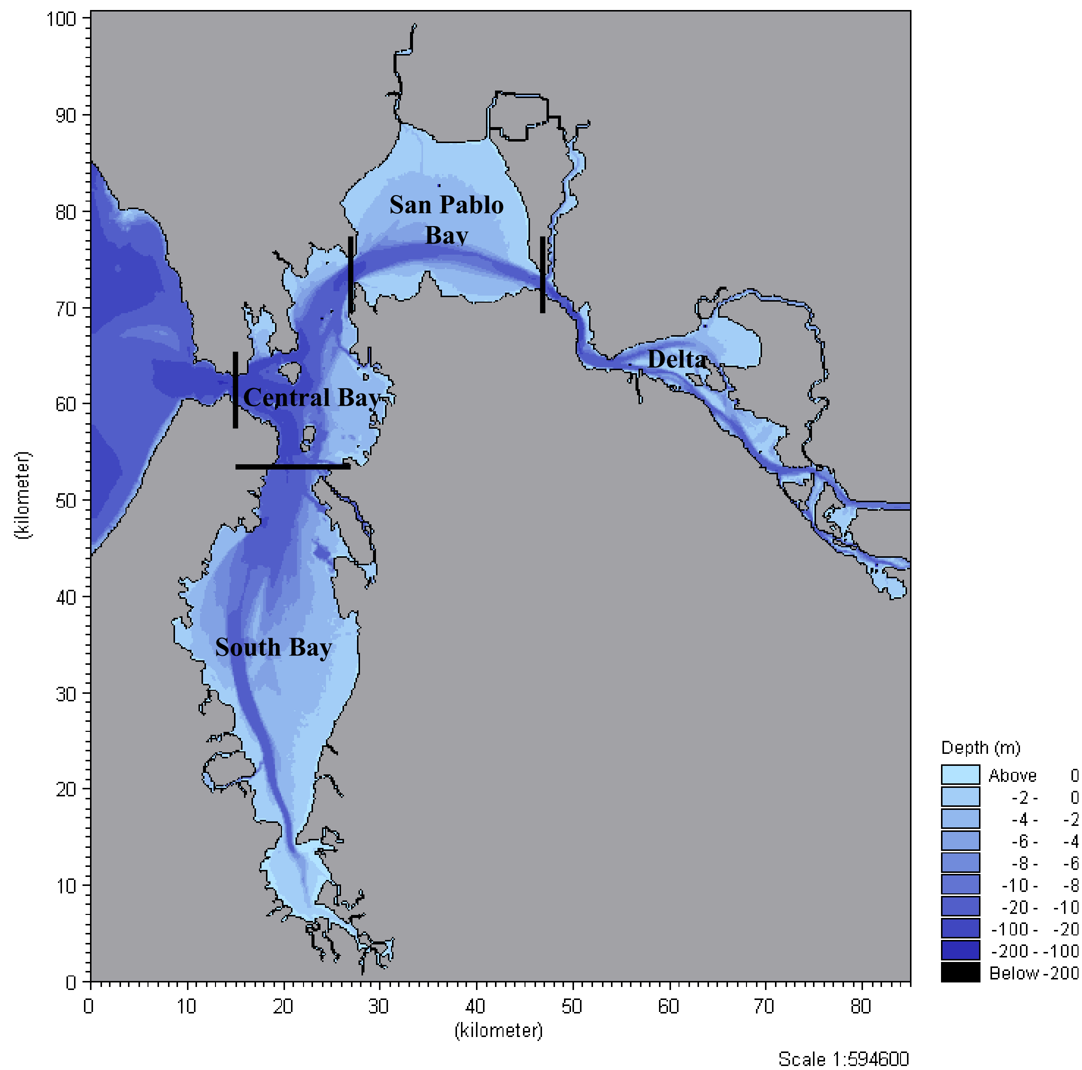
SPM Se concentration are believed to be the best predictor of bivalve tissue Se concentrations. As would be expected, the most highly affected area under the Delta-Chipps Island Disposal Alternative discharge scenario is the Delta, where average Se concentrations in tissue are predicted to be approximately 70 percent higher than the concentrations under existing conditions (Table G1-15). Closest to the discharge point, predicted tissue concentrations may be more than double the concentrations under existing conditions.

Under the Delta-Carquinez Strait Disposal Alternative discharge scenario, the most highly affected area is San Pablo Bay, where average Se concentrations in tissue are predicted to approximately 30 percent higher than the concentrations under existing conditions. Closest to the discharge point, predicted tissue concentrations may be up to double the concentrations under existing conditions.

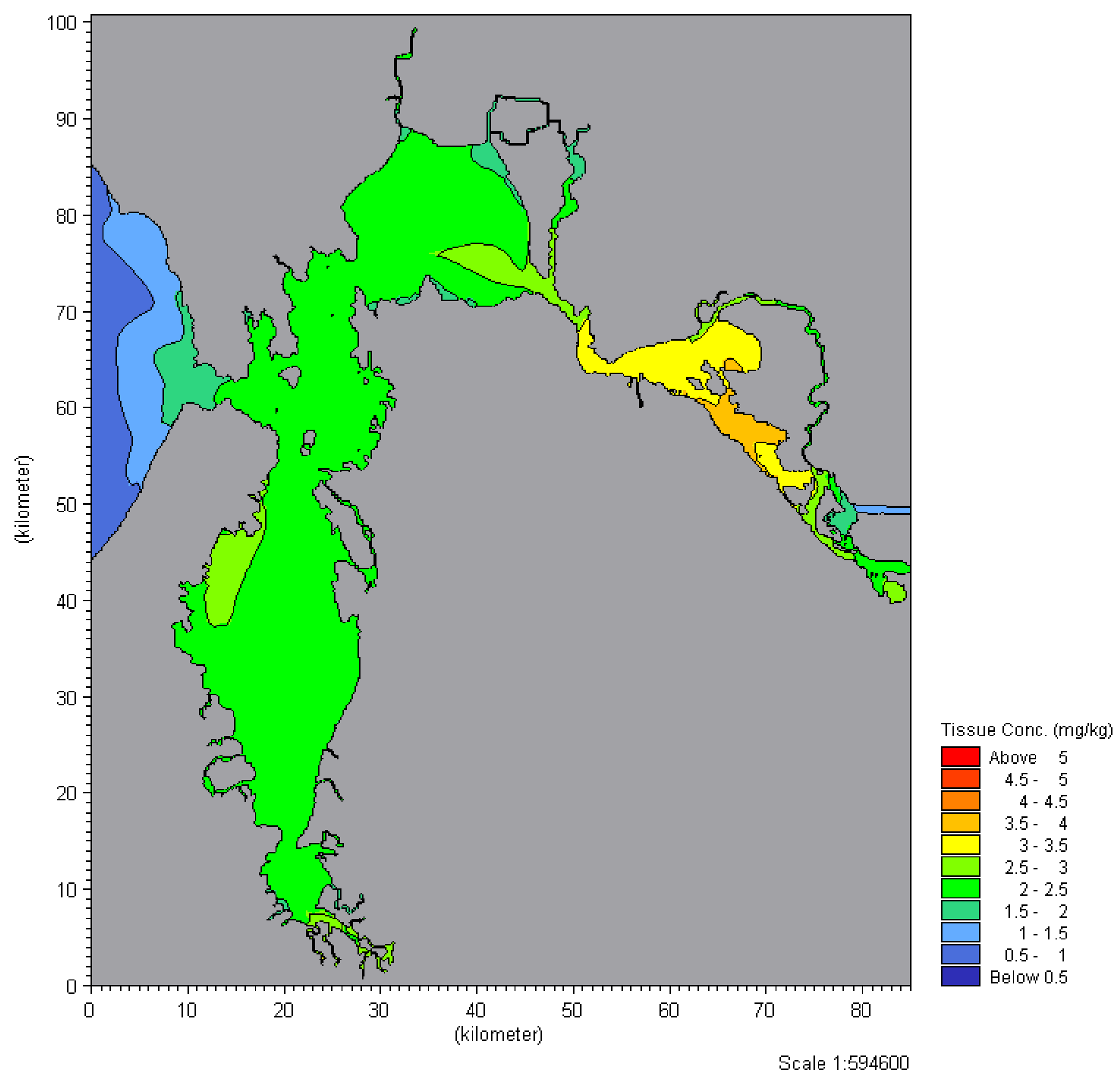
G1.2.8 Comparison to Effects Benchmarks

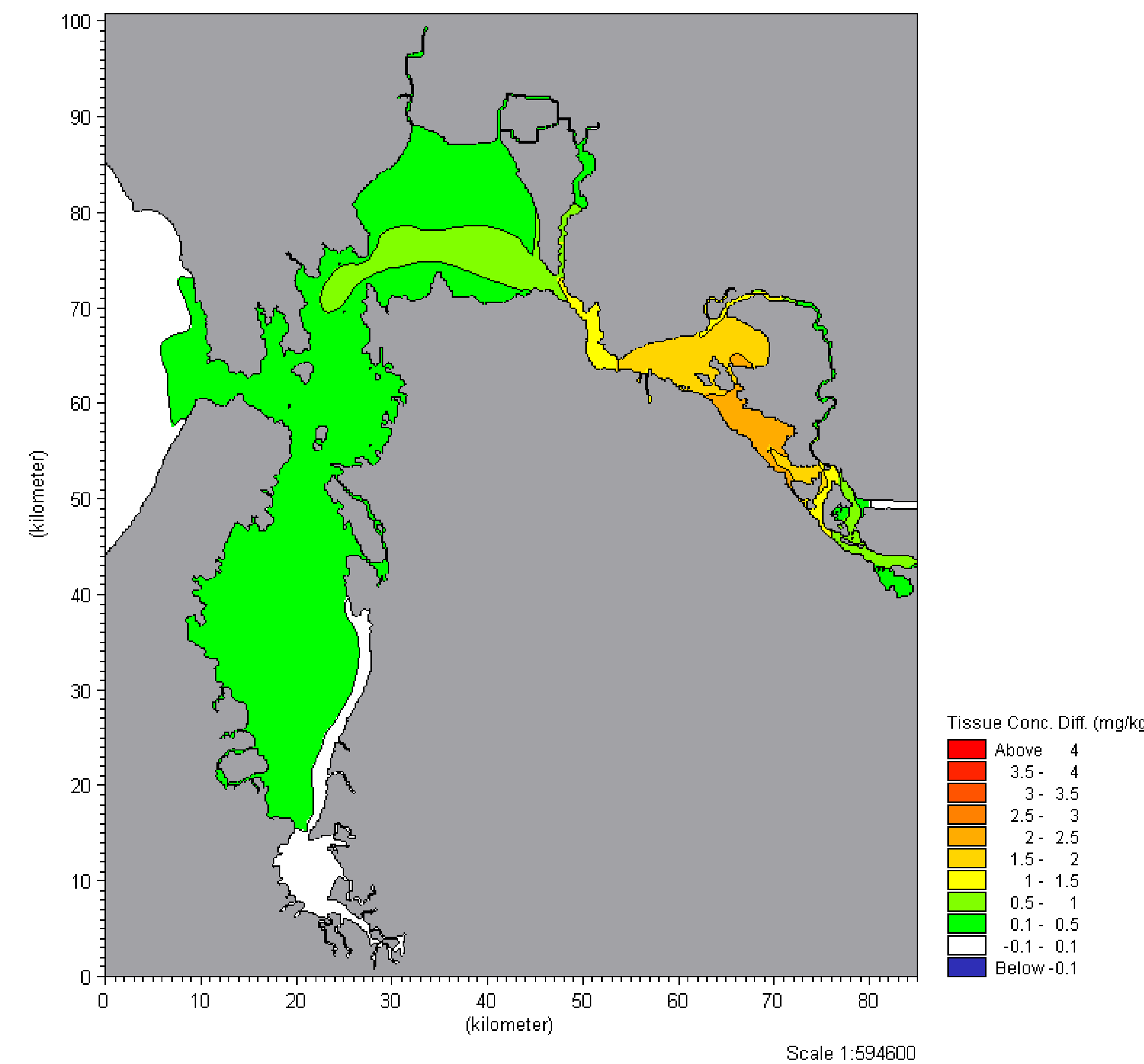
To determine whether the predicted increases in Se concentrations in bivalve tissues are likely to result in effects to upper trophic level ecological receptors such as benthic-feeding birds and fish, a literature search was conducted to identify prey tissue concentrations of Se that are associated with adverse effects to predators.

Luoma et al. (1992) state that Se concentrations of 9 to 10 mg/kg (dry weight) occur in the most contaminated individuals of the clam *Corbicula fluminea* in Suisun Bay, and that this is the concentration at which dietary toxicity is observed in fish in laboratory studies. Lemly (1996) reviewed data on Se toxicity and assigned a hazard ranking for dietary toxicity and reproductive failure in fish and aquatic birds from ingestion of Se-contaminated macroinvertebrates. A Se concentration of 2 to 3 mg/kg (dry weight) was assigned a hazard ranking of minimal toxicity, 3 to 4 mg/kg was assigned a hazard ranking of low toxicity, 4 to 5 mg/kg was assigned a hazard ranking of moderate toxicity, and greater than 5 mg/kg was assigned a hazard ranking of high



URS	17324004 San Luis Drainage Feature Re-evaluation	Bathymetry and Areas Selected for Average Tissue Concentration Calculations	FIGURE G1-25





URS	17324004 San Luis Drainage Feature Re-evaluation	Predicted Mean Bivalve Tissue Concentration (Dry Water Year) Adsorbed Selenium Uptake from Chipps Discharge–Predicted (LEFT), Difference (RIGHT)	FIGURE G1-26

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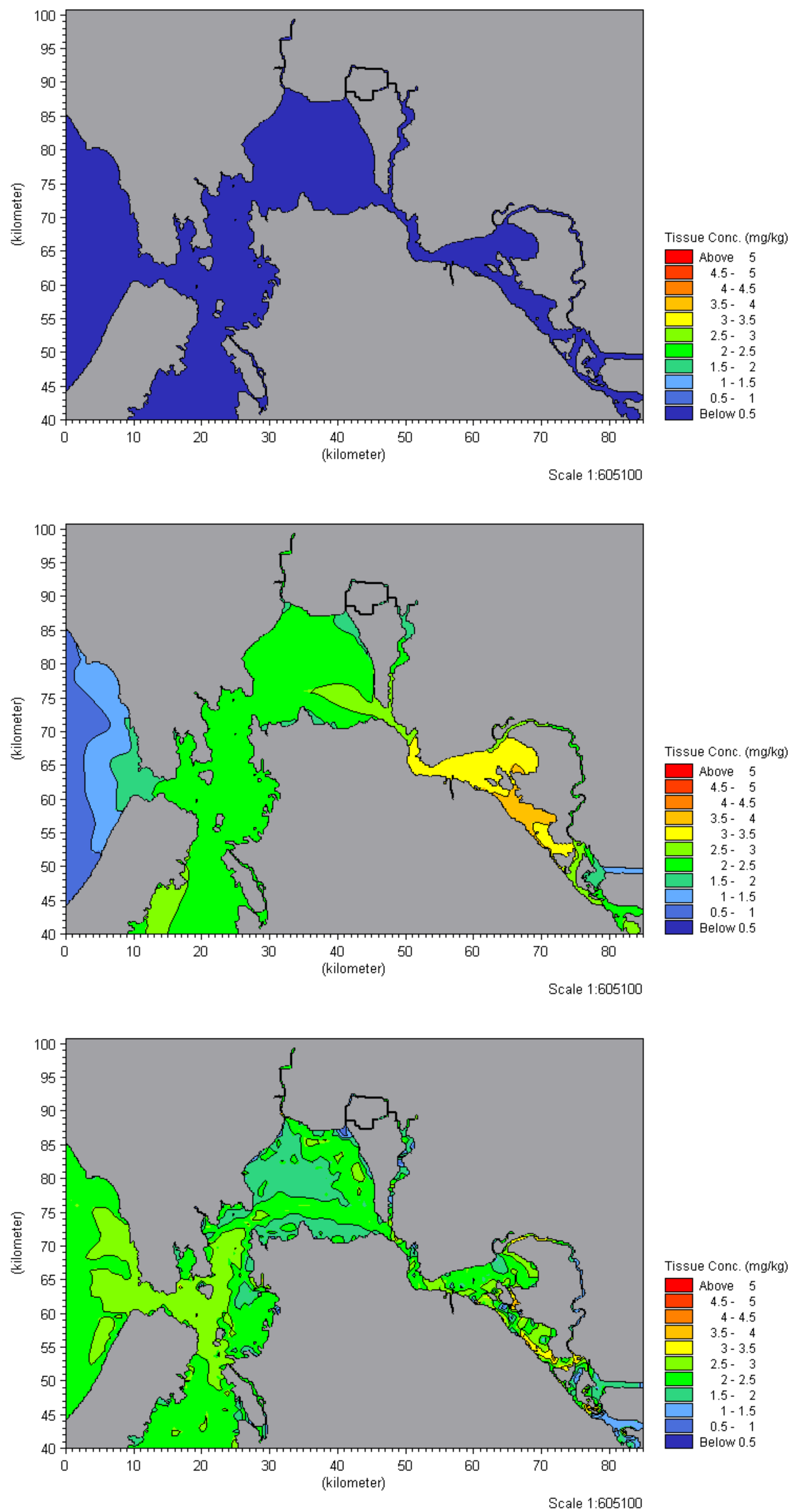
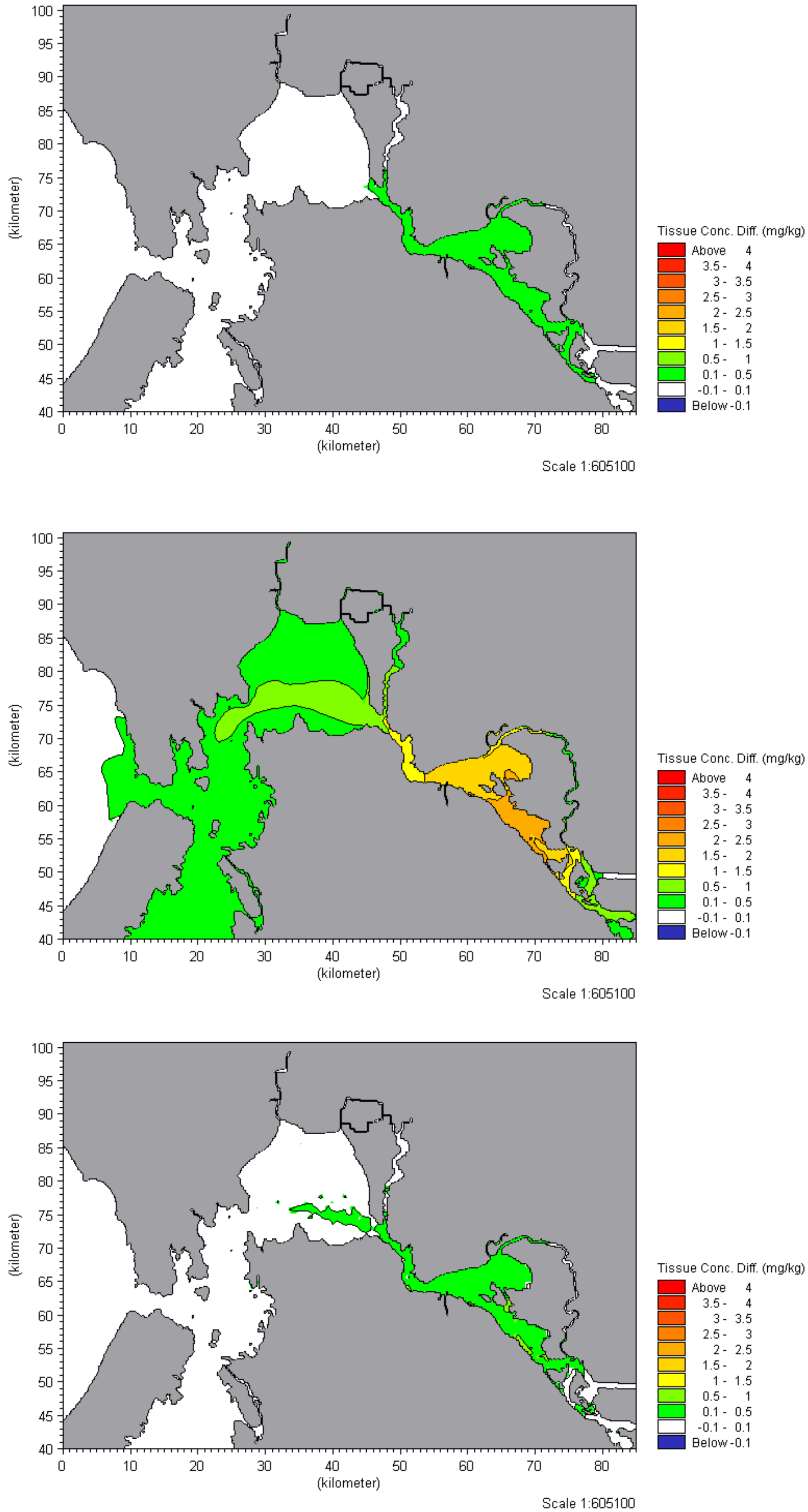
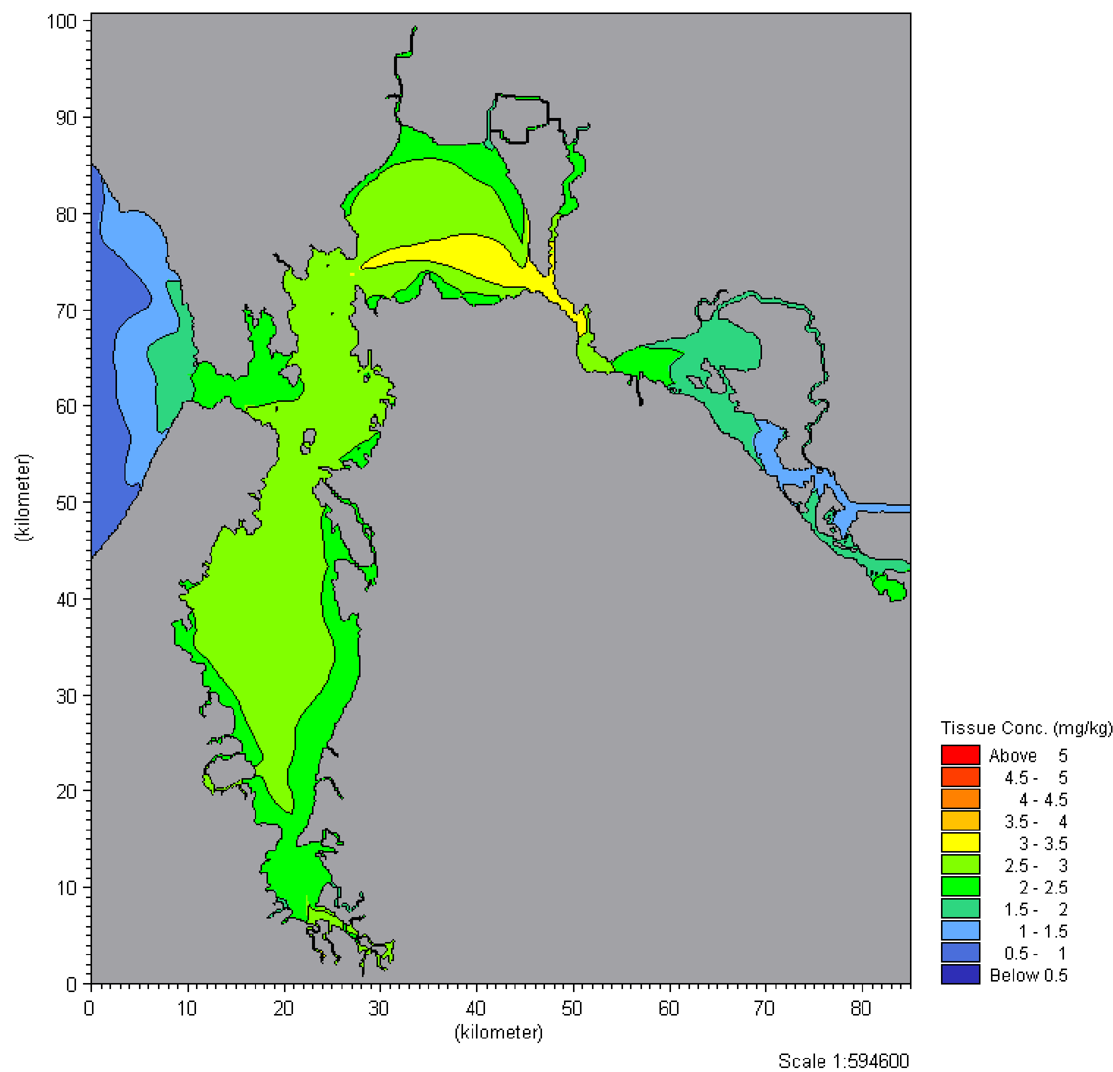
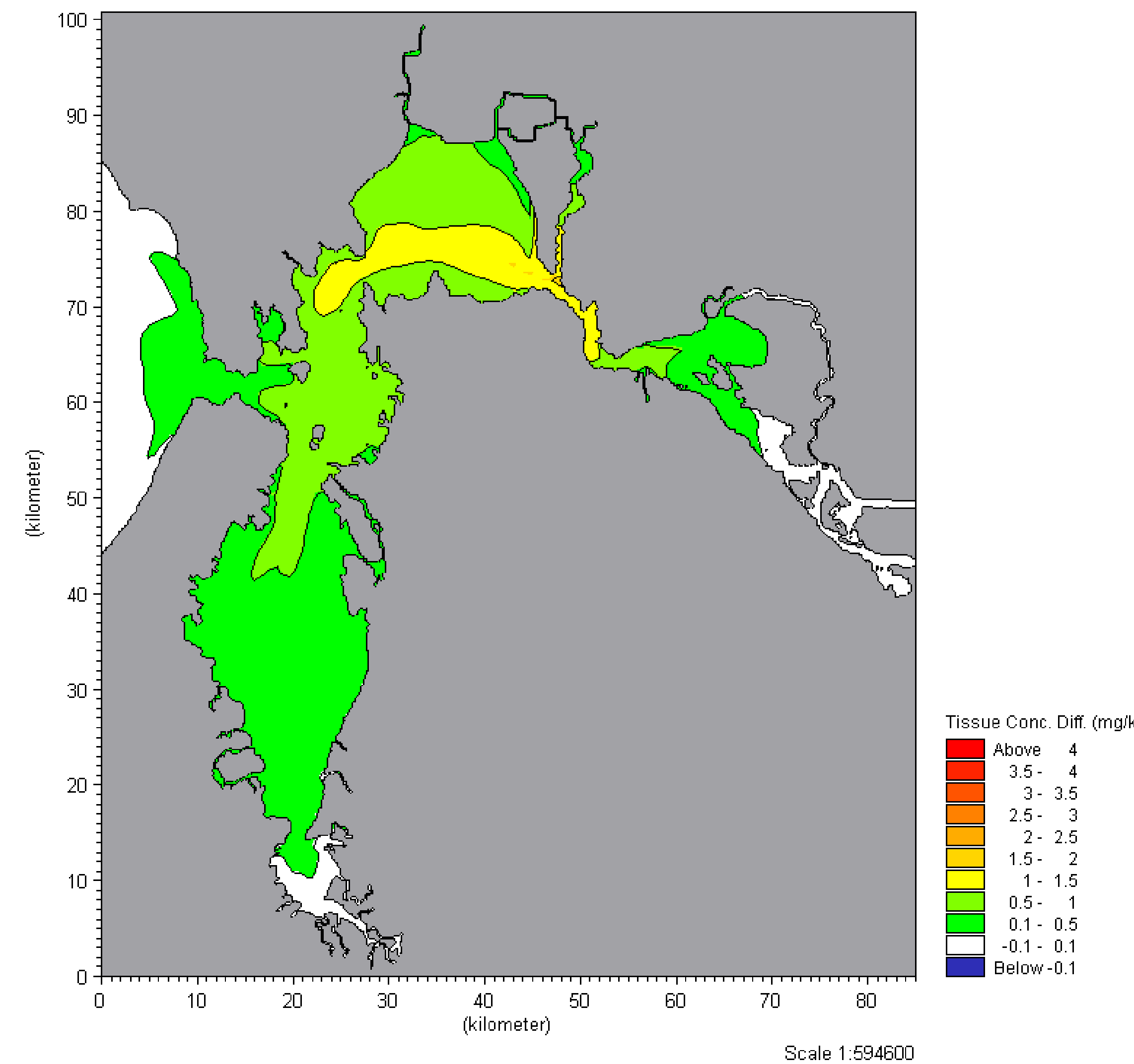


URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Chipps Discharge (June-November Dry Water Year) Bivalve Tissue Concentration (mg/kg) from Dissolved (Top), Adsorbed (Middle), and Benthic (Bottom) Selenium	FIGURE G1-27a

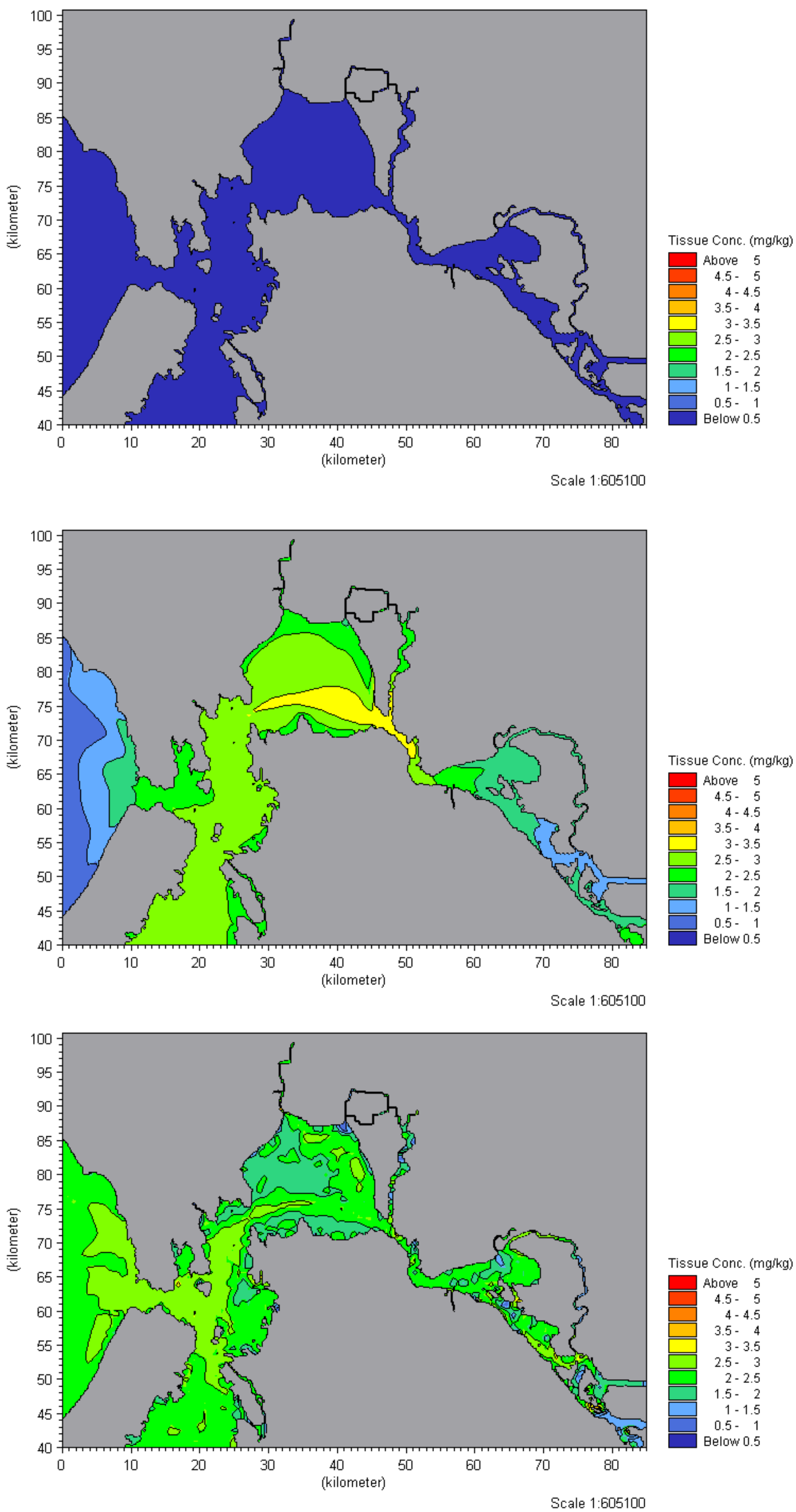


URS	17324004	MIKE 21 Chipps Discharge (June-November Dry Water Year) Change in Bivalve Tissue Concentration (mg/kg) from Dissolved (Top), Adsorbed (Middle), and Benthic (Bottom)	FIGURE G1-27b
	San Luis Drainage Feature Re-evaluation		

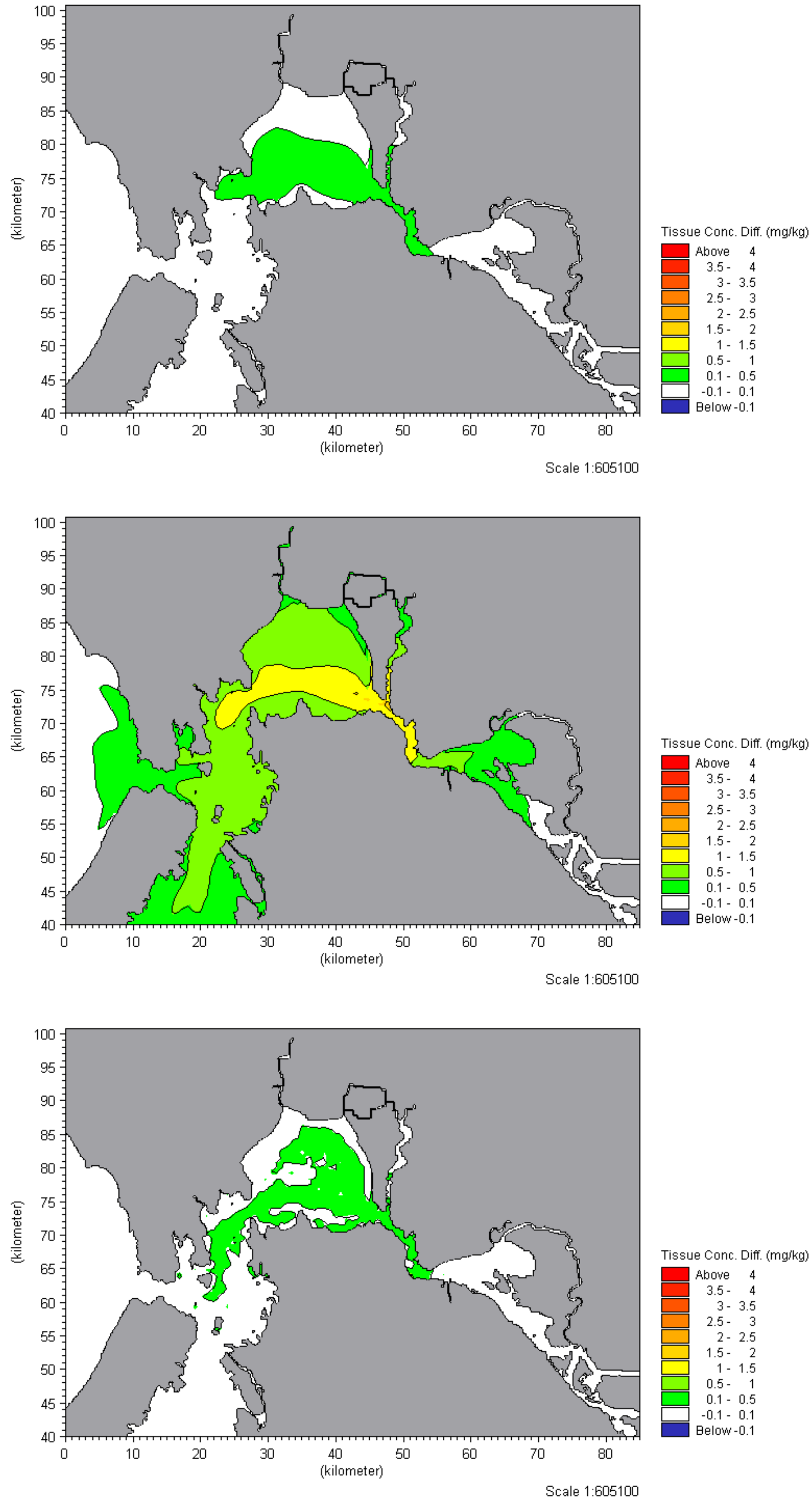




URS	17324004 San Luis Drainage Feature Re-evaluation	Predicted Mean Bivalve Tissue Concentration (Dry Water Year) Adsorbed Selenium Uptake from Carquinez Discharge–Predicted (LEFT) Difference (RIGHT)	FIGURE G1-28



URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Carquinez Discharge (June-November Dry Water Year) Bivalve Tissue Concentration (mg/kg) from Dissolved (Top), Adsorbed (Middle), and Benthic (Bottom) Selenium	FIGURE G1-29a



URS	17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Carquinez Discharge (June-November Dry Water Year) Change in Bivalve Tissue Concentration (mg/kg) from Dissolved (Top), Adsorbed (Middle), and Benthic (Bottom)	FIGURE G1-29b

toxicity. Peterson and Nebeker (1992) described the results of several comprehensive reviews on the effects of Se on animals. They concluded that it is widely agreed that chronic exposure to Se dietary concentrations greater than 5 mg/kg can result in adverse effects to birds and mammals.

Under the Delta-Chipps Island Disposal Alternative, the highest predicted bivalve concentrations are under 4 mg/kg. Under the Delta-Carquinez Strait Disposal Alternative, the highest predicted bivalve concentrations are under 4 mg/kg. Based on the information presented above, these concentrations are not expected to result in significant toxicity to upper trophic level receptors. However, it should be noted that these are general comparisons, and that localized effects have the potential to occur at areas with the highest Se concentrations, especially if the more bioavailable forms of Se are present.

G1.2.9 Summary of Surface-Water Resources and Bioaccumulation Impacts

Table G1-17 summarizes the results of the surface-water resources and bioaccumulation analysis.

Table G1-14
Predicted Mean Bivalve Tissue Concentration Due to Bioconcentration of Dissolved Selenium (June-November)

Station Name	Predicted Mean Tissue Concentration in *Mytelus galloprovincialis* (mg/kg dry weight)		
	No Action	Chipps Island Discharge	Carquinez Strait Discharge
Delta	0.17	0.34	0.21
San Pablo Bay	0.20	0.25	0.30
Central Bay	0.21	0.25	0.28
South Bay	0.24	0.26	0.28

Table G1-15
Predicted Mean Bivalve Tissue Concentration Due to Bioaccumulation of Selenium Adsorbed on Suspended Particulate Material (June-November)

Station Name	Predicted Mean Tissue Concentration in *Crassotrea gigas* (mg/kg dry weight)		
	No Action	Chipps Island Discharge	Carquinez Strait Discharge
Delta	1.88	3.21	2.20
San Pablo Bay	2.64	3.05	3.44
Central Bay	2.61	2.95	3.29
South Bay	2.20	2.36	2.50

Table G1-16
Predicted Mean Bivalve Tissue Concentration Due to Bioaccumulation of Selenium in Benthic Sediments (June-November)

Station Name	Predicted Mean Tissue Concentration in *Crassotrea gigas* (mg/kg dry weight)		
	No Action	Chipps Island Discharge	Carquinez Strait Discharge
Delta	2.09	2.29	2.13
San Pablo Bay	2.04	2.09	2.13
Central Bay	2.43	2.47	2.50
South Bay	2.11	2.12	2.13

Table G1-17
Preliminary Environmental Impact Summary Relative to the No Action Alternative

Anticipated Environmental Effect	No Action (*Compared to Existing Conditions)*	Out-of-Valley (*Compared to No Action)* Delta Discharge Chipp's Island	Delta Discharge Carquinez Strait	Ocean Discharge Point Estero	In-Valley (*Compared to No Action)*
Increased salinity in delta drinking water intakes	Less-than-Significant Adverse Impact	Less-than-Significant Adverse Impact	Less-than-Significant Adverse Impact	Beneficial Impact	Beneficial Impact
Degraded water quality in San Joaquin River and tributaries	Potentially Significant Adverse Impact	Beneficial Impact	Beneficial Impact	Beneficial Impact	Beneficial Impact
Increases of Se in Bay-Delta waterfowl	Less than significant adverse impact	Potentially significant adverse impact	Potentially significant adverse impact	Less than significant adverse impact	Less than significant adverse impact

G1.3 GROUNDWATER RESOURCES

G1.3.1 Affected Environment

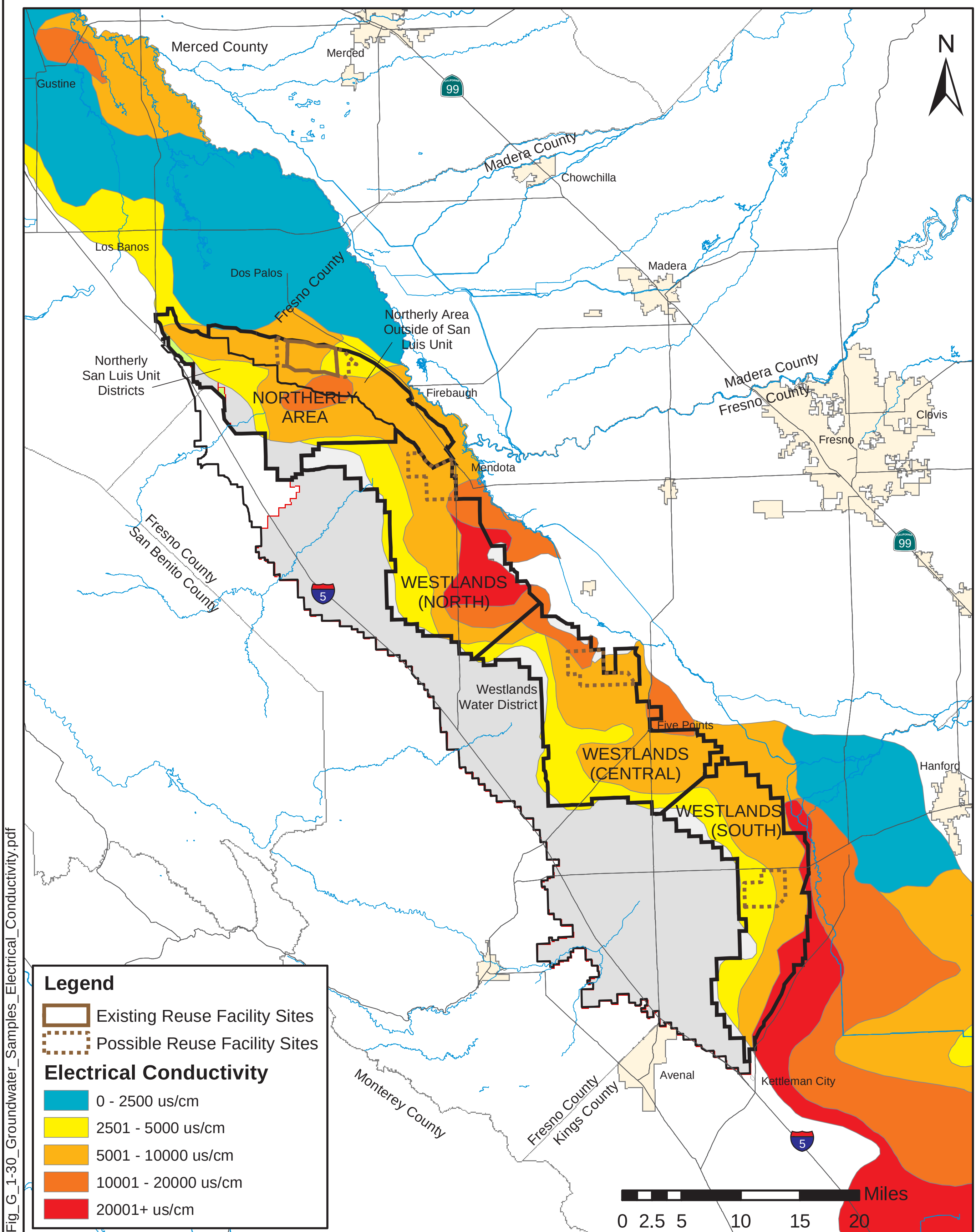
G1.3.1.1 Existing Groundwater Resources

The San Joaquin River basin has been identified as containing 26 groundwater basins with 9 of the basins classified as significant sources of groundwater. The total area of the 9 groundwater basins is approximately 13,700 square miles, of which San Joaquin Valley alone comprises about 13,500 square miles. The California Department of Water Resources estimates an annual overdraft of approximately 205,000 AF of groundwater. This overdrafting of groundwater has caused ground subsidence since the mid-1920s. By 1970, 5,200 square miles of the valley were affected and maximum subsidence exceeded 28 feet in an area west of Mendota. Much of this area is now served by the Central Valley Project's San Luis Unit.

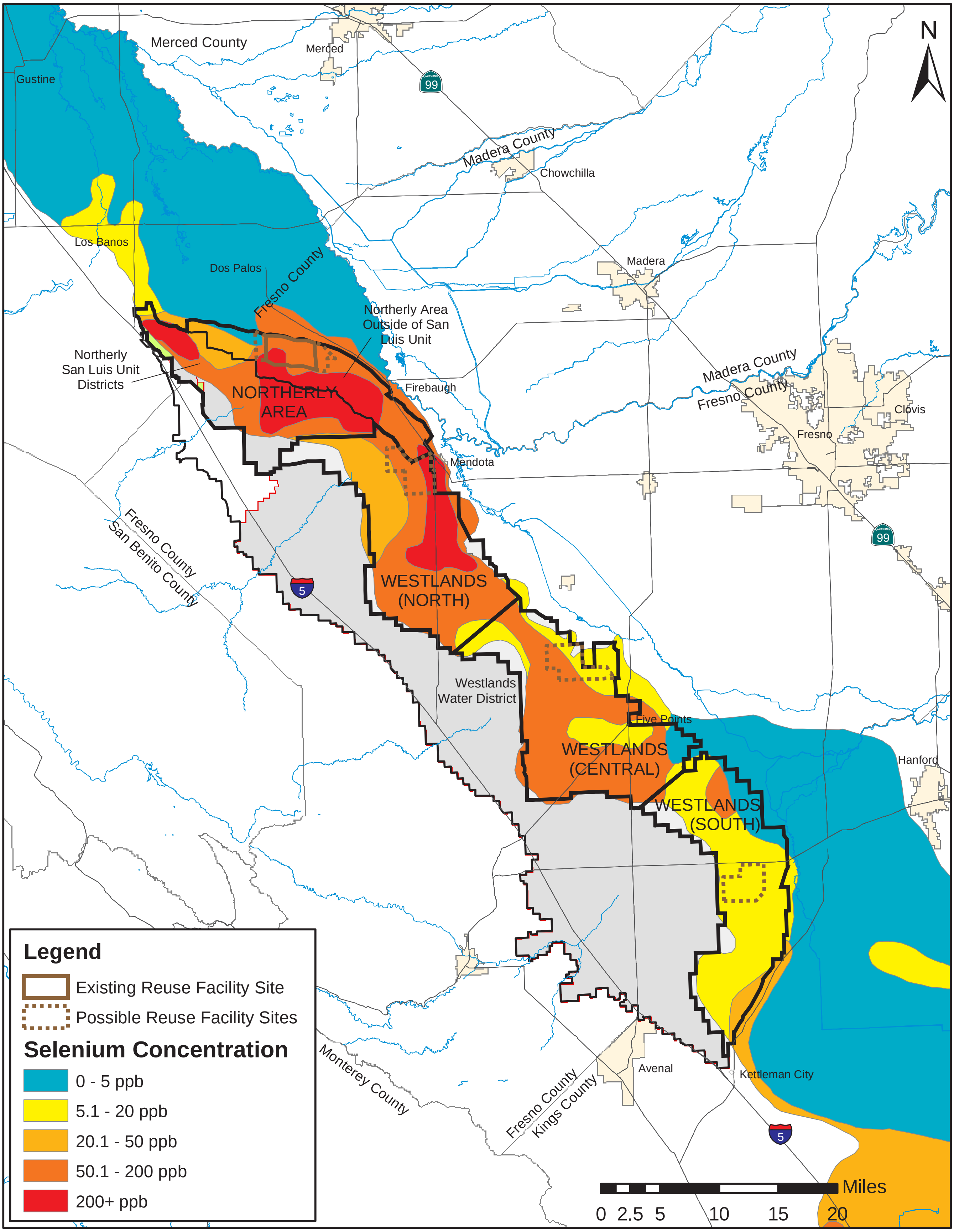
Irrigated agriculture has altered both groundwater flow and quality. Significant portions of the groundwater in the study area exceed the CWA's recommended TDS concentration. The dissolved solids content of the groundwater averages about 500 ppm, but ranges from 64 to 10,700 ppm. Calcium, magnesium, sodium, bicarbonates, Se, sulfates, and chlorides are all present in significant quantities.

Figures G1-30 through G1-34 show the estimated quality of shallow groundwater based on samples collected as a part of the San Joaquin Valley Drainage Program in the mid-1980s. The contours were developed by Reclamation from individual observations in shallow wells.

The highest groundwater salinity and Se concentrations occur in areas of the highest native soil salinity. Harradine (1950) characterized western San Joaquin Valley soils in the 1940s. Alluvial fan soils are derived from the Diablo Range of the California Coast Range which borders the study area to the west. The Diablo Range consists of an exposed Cretaceous and upper Jurassic marine core assemblage overlain by and juxtaposed with Cretaceous and Tertiary marine and

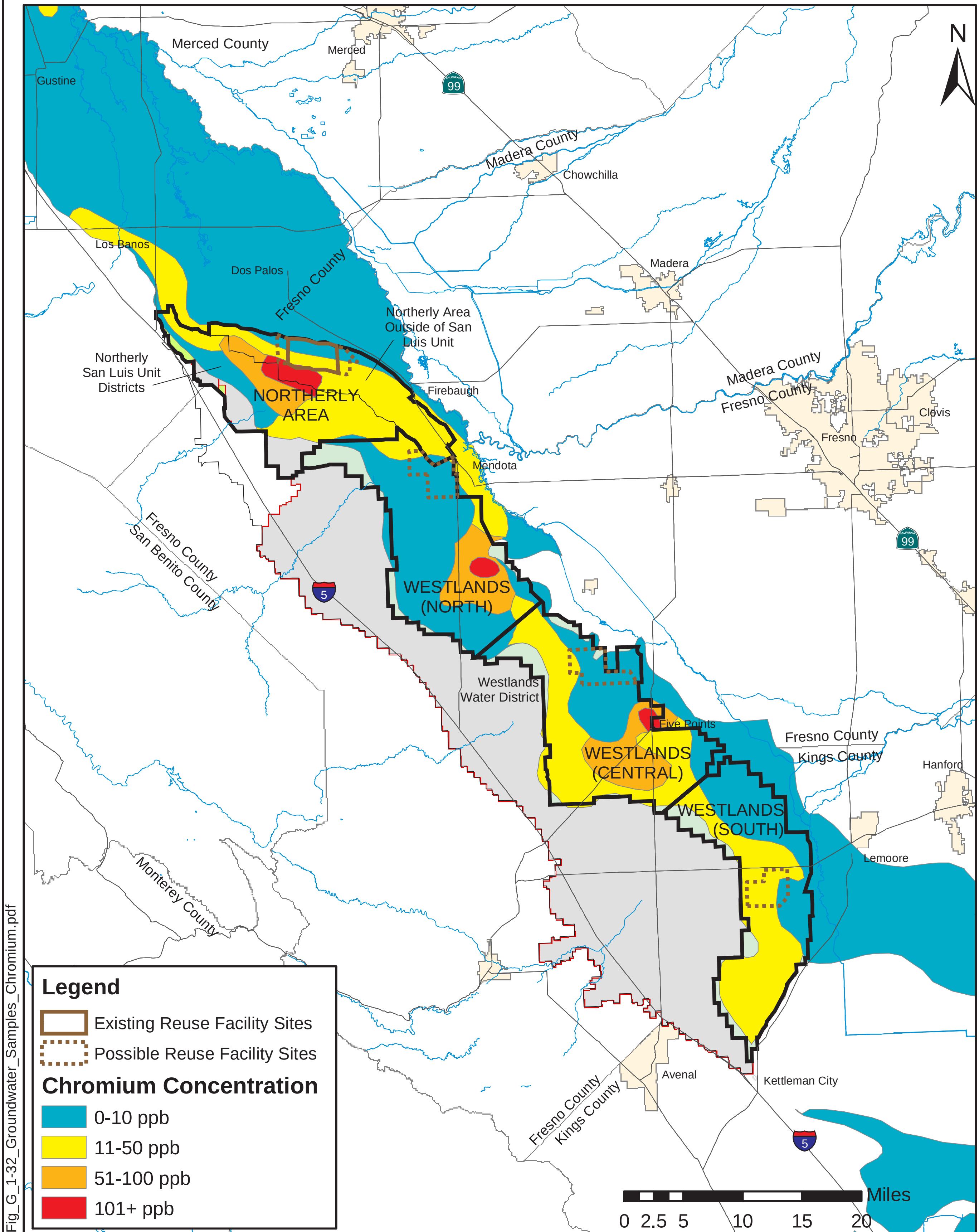


URS	San Luis Drainage Feature Re-evaluation 17324004	Electrical Conductivity In Shallow Groundwater	Figure G1-30

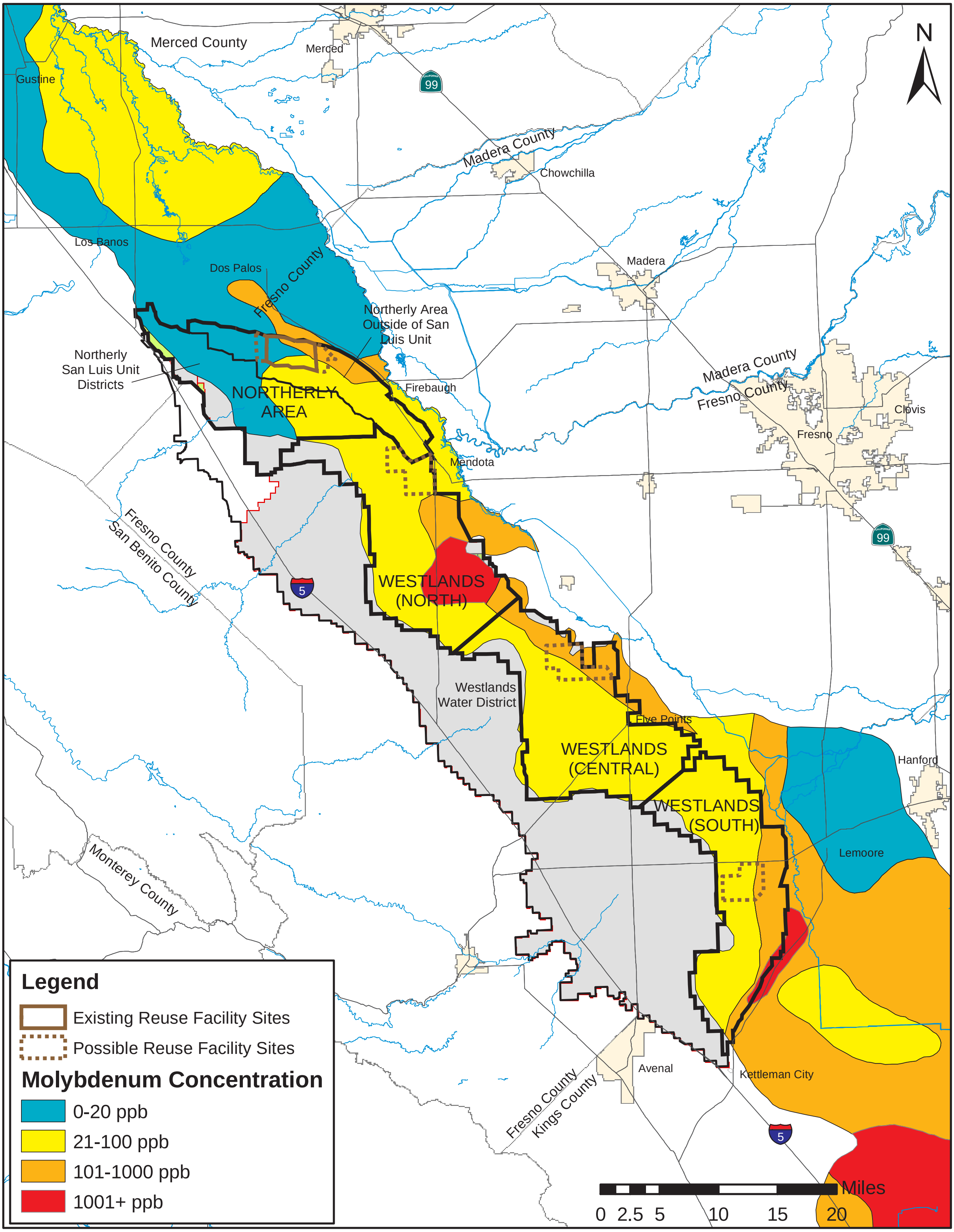


Fig_G_1-31_Groundwater_Samples_Selenium.pdf

URS	San Luis Drainage Feature Re-evaluation 17324004	Selenium Concentration In Shallow Groundwater	Figure G1-31

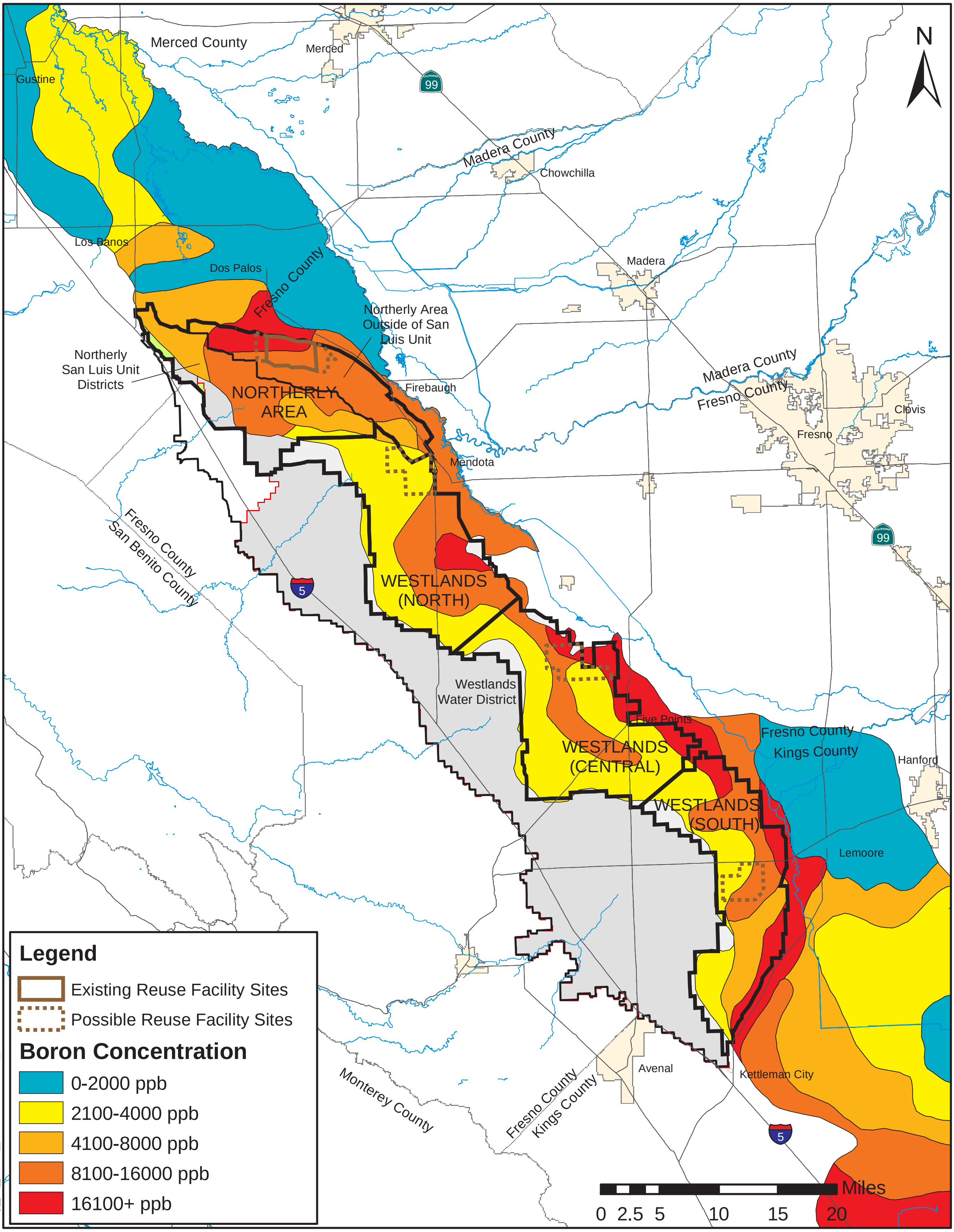


URS	San Luis Drainage Feature Re-evaluation	Chromium Concentration In Shallow Groundwater	Figure G1-32
	17324004		



Fig_G_1-33_Groundwater_Samples_Molybdenum.pdf

URS	San Luis Drainage Feature Re-evaluation 17324004	Molybdenum Concentration In Shallow Groundwater	Figure G1-33



Fig_G_1-34_Groundwater_Samples_Boron.pdf

URS	San Luis Drainage Feature Re-evaluation 17324004	Boron Concentration In Shallow Groundwater	Figure G1-34

continental deposits. The soils in the basin trough at the eastern edge of the study area are of mixed origin; Sierra Nevada igneous and metamorphic rocks and Diablo Range sediments. Soils are generally coarse-grained in the upper- and middle-alluvial fan areas and fine grained in the lower-alluvial-fan and basin trough areas.

Soil salts in the study area contain calcium, sulfate, sodium, magnesium and inorganic carbon. Prior to irrigation, soils contained sodium, magnesium, sulfate evaporite salts such as thenardite (sodium sulfate), mirabolite (sodium sulfate) and bloedite (magnesium, sodium sulfate) (Presser et al. 1990) and calcium sulfate (gypsum) and calcium carbonate. Irrigation dissolves the more soluble evaporite salts and substantial amounts of calcite (calcium carbonate) and gypsum (calcium sulfate) remain in irrigated soils (e.g. Tanji et al. 1977). Presser and Swain (1990) reported Se concentrations ranging from 1 to 25 ppm in these evaporite salts present in the saline and seleniferous geological formations in the Diablo Range and in unirrigated soils. In contrast, Deverel and Fujii (1988) reported that Se is probably not present in gypsum. Irrigation of saline soils dissolved soluble soil salts and Se and moved them to the groundwater. Subsequent rises in the groundwater table further increased groundwater salinity and Se concentrations (Deverel and Fujii 1988; Deverel and Fio 1991).

Percolation of irrigation water past crop roots, pumping of groundwater from deep wells, and imported surface water used for irrigation have combined to create large downward hydraulic-head gradients. As a result, the soil salts and Se in the irrigation water are leaching from the unsaturated soil zone and increasing salt and Se concentrations in the groundwater. A USGS report (Dubrovsky and Deverel 1989) indicated that irrigation had impacted the upper 20 to 150 feet of the saturated groundwater zone. This poor quality groundwater zone is moving downward in response to recharge from above the water table and pumping from deep wells. In 1995 Belitz and Phillips estimated the downward velocity of the poor quality groundwater at about 1 foot per year, which suggests that most of the regions groundwater will be affected within 200 to 400 years. However, drinking water wells are typically over 300 feet deep and several layers of aquifers and clay lenses lie between the upper levels affected by irrigation and the drinking water aquifer.

Ken Schmidt and Associates (pers. comm., 2002) indicate that westward movement of saline groundwater affects the quality of pumped water in the semiconfined zone near Mendota and Fresno Slough. They describe a front of saline water parallel to Fresno Slough as the result of groundwater flowing downward and westward from western San Joaquin Valley, which appears to have impacted city of Mendota wells. For example, water quality data for city of Mendota well number 5 indicate increasing trends in salinity in the late 1990s.

In western San Joaquin Valley, the groundwater system is divided into a lower confined zone and upper semiconfined zone, separated by the Corcoran Clay (Figure G1-35). The water table is located within the semiconfined zone. In the upslope areas, the water table is typically located several hundred feet below land surface. In contrast, most downslope areas are underlain by a shallow water table within 7 feet of land surface (Belitz and Heimes 1990).

Under natural conditions, the shallow water table existed in areas along the valley floor and adjacent to the San Joaquin River. Groundwater recharge occurred primarily by infiltration of runoff in Coast Range streams. Groundwater discharge was primarily by evapotranspiration and seepage to the San Joaquin River.

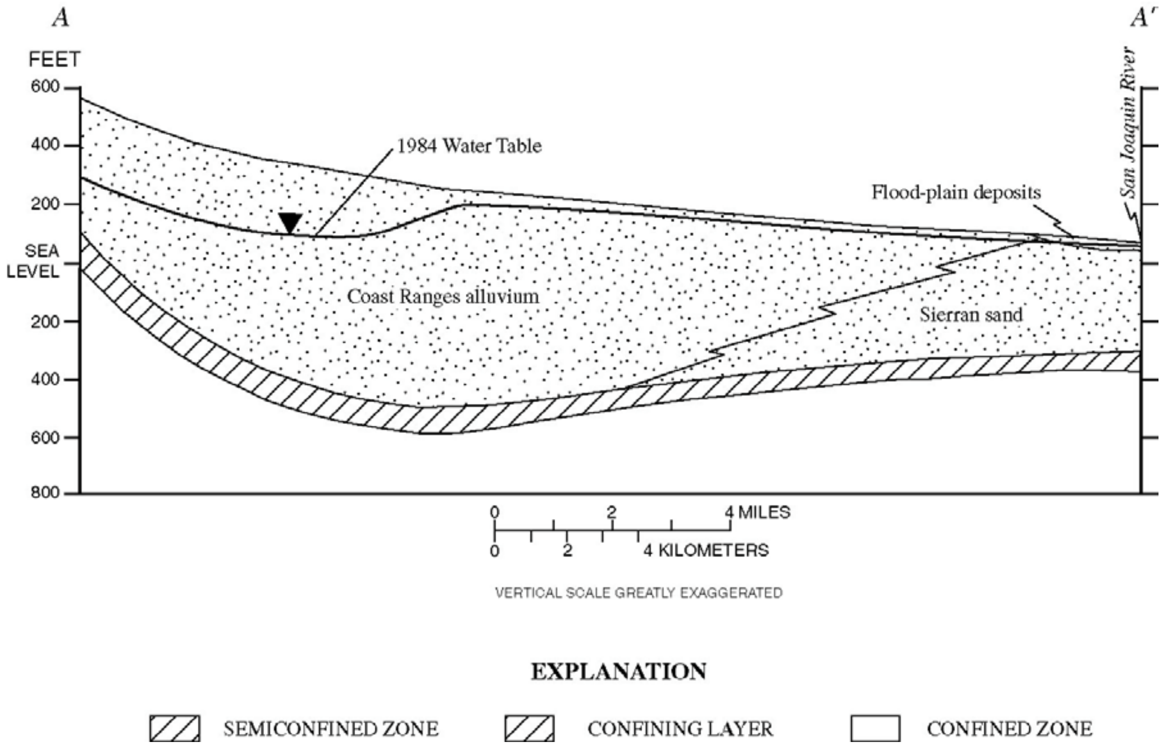


Figure G1-35 Geohydrologic section of western San Joaquin Valley (modified from Belitz and Heimes 1990)

During the past 40 years, recharge increased dramatically as a result of imported irrigation water. Irrigated agriculture has altered both groundwater flow and quality. Percolation of irrigation water past crop roots, pumpage of groundwater from deep wells, and imported surface water used for irrigation have combined to create large downward hydraulic-head gradients. The salts in the irrigation water, and soil salts leached from the unsaturated zone, increased salt and Se concentrations in groundwater (Dubrovsky and Deverel 1989). In low-lying areas of the valley, and where the water table is within 7 feet of land surface, evaporation from the shallow water table further increased salt and Se concentrations.

Irrigation recharge increases groundwater storage and causes the water table to rise. Drainage systems remove groundwater and prevent water logging and salt accumulation in the root zone. Continued recharge without drainage will increase the area underlain by the shallow water table and continue soil and groundwater salinization. In this section, estimated groundwater impacts as a result of irrigation and drainage activities under the No Action, Out-of-Valley, and In-Valley alternatives are described. A regional groundwater-flow model was employed to estimate changes in groundwater storage and water-table depths under different management alternatives. Shallow groundwater samples were collected as a part of this study from wells sampled in 1984 by the USGS to assess dissolved solids, Se, boron, molybdenum, and other trace element concentrations. The chemical data provided an empirical assessment of the constituent concentration changes in groundwater during the past 18 years.

G1.3.2 Environmental Consequences

The water-table rise is the primary groundwater impact, which produces several related effects.

- **Bare soil evaporation.** Evaporation from the shallow water table can cause salinity increases in groundwater and soil (Deverel and Fujii 1988). Evaporation rates can be reliably estimated in the range between 0.0 to 0.4 foot/year. Evaporation rate increases of 0.1 foot/year or greater were considered to be a significant adverse impact and evaporation rate increases less than about 0.05 foot/year to have no impact.
- **Area underlain by shallow water table.** As the water table rises, the area underlain by the shallow water table expands. Belitz and others utilized a large amount of soil moisture, soil tension, and hydraulic conductivity data for Panoche clay loam, the predominant western San Joaquin Valley soil, and concluded that bare-soil evaporation is significant when the water table is within 7 feet of land surface (Belitz, Phillips, and Gronberg 1993). The groundwater-flow model can be utilized to reliably estimate water-table depth at the scale of individual water districts. Therefore, a 10-square-mile or greater increase in area underlain by a water table within 7 feet of land surface was considered to be a significant adverse impact, and area changes less than several square miles were considered to have no impact.
- **Groundwater salinity.** Groundwater salinity can increase as a result of increased evaporation from the shallow water table. Groundwater salinity changes affect drainwater quality. Both measured groundwater salinity increases, as inferred from repeat wellwater samples collected in 1984 and 2002, and simulated changes in groundwater salinity under representative conditions were considered. An estimated 10 percent increase in groundwater salinity was considered to be a significant adverse impact.

G1.3.2.1 Methodology and Assumptions

A transient, three-dimensional, finite-difference groundwater-flow model was utilized to estimate changes in water-table depth and its consequences to bare-soil evaporation, area affected by a water table within 7 feet of land surface, and groundwater salinity. The USGS developed the model for the San Joaquin Valley Drainage Program. The model represents about 212,500 acres of the approximately 604,000-acre Westlands Water District (about 36 percent), and about 88,000 acres of the 97,400-acre Grassland Drainage Area (GDA) (90 percent); the model represents 72 percent (34,600 acres) of the currently 48,000-acre drained area within the GDA.

The model utilizes mean annual recharge and pumpage data to project long-term changes in annual water-table depth. It employs a linear function to calculate evaporation from the shallow water table. The evaporation rate is zero when the water table is more than 7 feet below land surface, and a maximum evaporation rate of 1 foot/year is simulated for water-table depths 4 feet and less below the land surface. HydroFocus, Inc. (1998) evaluated model-projected groundwater levels and drainflow during the period 1989–97. They updated boundary conditions, recharge, and pumpage data and concluded updated model results are acceptable to evaluate long-term changes in water-table depth.

In western San Joaquin Valley, soil and groundwater salinity is spatially variable (Fujii, Deverel, and Hatfield 1988; Corwin, Rhaodes, and Vaughan 1996; Corwin et. al. 1999), which limited the ability to establish historical and present-day salinity values and project future salinity changes under different management alternatives. Geochemical analyses and recent groundwater sample data were utilized to provide insight into anticipated groundwater quality changes over time. In August 2002, shallow wells installed by the Bureau of Reclamation (Reclamation) during the 1960s, 1970s, and 1980s were sampled to depths of 18 to 30 feet. Although many of the previously sampled wells no longer exist or have been replaced, 20 wells were successfully located and sampled. The samples were analyzed for TDS, alkalinity, chloride, sulfate, Se, molybdenum, arsenic, aluminum, barium, beryllium, cadmium, chromium, calcium, magnesium, sodium, potassium, copper, iron, manganese, and silica. When laboratory results are available, the results reported previously by the USGS (Deverel et. al. 1984; Deverel and Gallanthine 1989) and samples we collected from identical wells in August 2002 will be compared.

G1.3.2.2 Alternatives Considered

An Out-of-Valley scenario, whereby drainwater is exported for discharge at several locations, and an In-Valley scenario where drainwater is treated and managed within San Joaquin Valley were considered. The Out-of-Valley scenario considers drainwater discharge at one of two possible Delta locations (Chipps Island or Carquinez Strait) and a Pacific Ocean location (Point Estero). Simulated groundwater impacts from these alternatives were compared to the No Action scenario. Assumptions for the No Action, Out-of-Valley, and In-Valley scenarios are summarized below.

No Action

For the No Action Alternative, the following hydrologic conditions from 2001 to 2050 were simulated:

- In 2001, about 48,000 acres were drained within the GDA and a substantial portion of the drainwater was discharged to the San Joaquin River through the Grassland Bypass Project. After 2009, when the Grassland Bypass Project agreement ends, we assumed that drainwater is no longer discharged to the river, but instead managed within the GDA. In contrast, Westlands has not discharged agricultural drainwater for more than 15 years, and the No Action Alternative simulated continued undrained conditions in Westlands.
- Without a drainage option, 68,000 acres within Westlands will be permanently retired from irrigated agriculture as follows: 51,000 acres retired by 2003 and 17,000 acres retired in 2004. We randomly distributed the retired lands throughout the drainage problem area. When land is permanently retired, irrigation ceases and consequently groundwater pumpage and surface-water deliveries are discontinued. The surface water is reallocated to other farmed lands within the district. The reallocated surface water was assumed to displace surface-water supplies that would be purchased from other entities. Hence, pumpage and irrigation recharge beneath active agricultural lands is not altered as a result of land retirement and the surface-water reallocation.
- Westlands long-term water supply plans assume future groundwater pumping equal to the basin’s “safe yield.” Their planned pumping level is about 7 percent less than the historical mean annual pumping rate. Therefore, the Westlands simulated mean annual pumping rate was reduced by 7 percent.
- Irrigation system improvements and practices on farmed lands in the GDA and Westlands remain the same as existing conditions.

- No new shallow groundwater management projects are implemented.
- In the GDA, drainwater recycling continues at current levels and the planned 3,000-acre In-Valley treatment facility begins operations in 2005. No new seepage reduction, drainwater recycling, or drainage reuse projects are implemented. After 2009, when the Grassland Bypass Project agreement ends, all drainwater remains within the GDA.

Out-of-Valley

The Out-of-Valley alternatives plan for drainwater transport and disposal at one of three discharge points: two in the Delta (Chipps Island and Carquinez Strait) and one in the Pacific Ocean (Point Estero). From a groundwater resource perspective, potential environmental impacts are approximately the same regardless of the discharge point selected. Hence, estimated impacts are essentially identical for all three potential Out-of-Valley alternatives. For the Out-of-Valley alternatives, the following hydrologic conditions from 2001 to 2050 were simulated:

- In 2005, 187,660 acres of new subsurface drainage systems are gradually installed within Westlands, and 6,000 acres of new drainage systems are gradually installed in the GDA (Figure G1-36). In Westlands, the drainage systems are randomly located within the 298,000-acre drainage-impacted area. In the GDA, the new drainage systems are randomly located within presently undrained portions of the 81,000-acre drainage-impacted area.

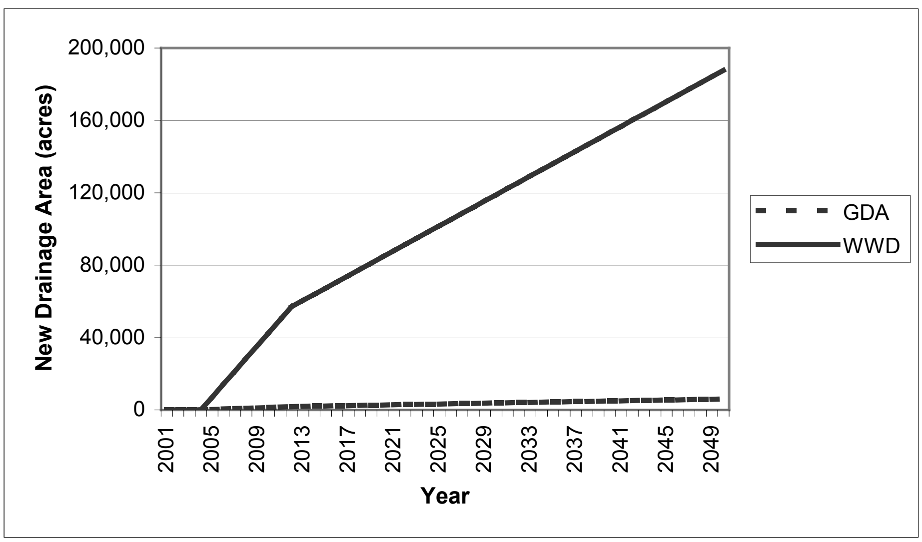


Figure G1-36 Simulated new drainage system buildup during 2001–2050 analysis period (acres)

- New drainage systems include both conventional and “shallow” designs. It was assumed 25 percent of the Westlands drainage systems and 10 percent of the new GDA drainage systems would be operated to manage shallow groundwater conditions.
- Drain conductance incorporates the effective conductivity of the drain/soil system and drain lateral density. An average conductivity for the drain/soil system of 210 feet/year was assumed (Fio 1994). The new drainage systems include both conventional and “shallow” designs. Laterals are spaced about 400 feet apart in the conventional systems and 150 feet

apart in the shallow systems. Hence, the shallow conductance term is presumably 2.7 times greater than the conventional conductance term. In the conventional systems, the drain lateral depths range from 7 to 8 feet below land surface (mean drain lateral depth of 7.5 feet below land surface), whereas the shallow drain lateral systems are installed from 4 to 5 feet below land surface (mean drain lateral depth of 4.5 feet below land surface).

- In 1999, Westlands acquired about 15,000 acres of land that they leased for dry farming in 2000. With drainage service provided, it was assumed that these lands would again be irrigated beginning in 2003. In addition, the 68,000 acres retired under the No Action Alternative would be returned to irrigated agricultural production.
- Irrigation system improvements and practices remain the same as existing conditions.
- Simulated Westlands annual groundwater pumping is reduced by 7 percent.
- In the GDA, seepage reduction projects decrease water-table recharge by 4,200 AF/year.
- Regional drainwater recycling continues in the GDA and is implemented in Westlands. Drainwater recycling displaces surface-water supplies and, therefore, does not impact the irrigation recharge rate. However, recycling increases irrigation-water salinity.
- About 28,000 acres of drainage reuse projects begin operation in 2005. Irrigation recharge beneath the reuse fields was assumed to be 1 foot/year. The direct application of drainwater increases salt loads in irrigation water applied to these lands.

In-Valley

The In-Valley Disposal Alternative utilizes similar irrigation and groundwater management options as the Out-of-Valley alternatives; however, treatment facilities and evaporation ponds are used to manage the drainwater within San Joaquin Valley. For this alternative, the following hydrologic conditions during the period 2001–2050 were simulated:

- In 2005, new subsurface drainage systems are gradually installed within Westlands (182,180 acres) and GDA (6,000 acres). In Westlands, the drainage systems are randomly located within the 298,000-acre drainage-impacted area. In the GDA, the new drainage systems are randomly located within presently undrained portions of the 81,000-acre drainage-impacted area.
- New drainage systems include both conventional and “shallow” designs. It was assumed that 25 percent of the Westlands drainage systems and 10 percent of the new GDA drainage systems would be operated to manage shallow groundwater conditions.
- The new drainage systems include both conventional and “shallow” designs. The shallow conductance term is presumably 2.7 times greater than the conventional conductance term. In the conventional systems, the mean drain lateral depth is 7.5 feet below land surface; whereas, the shallow drain lateral systems have a mean drain lateral depth of 4.5 feet below land surface.
- In 2000, Westlands acquired about 15,000 acres of land that they then leased for farming. With drainage service provided, it was assumed that these lands would again be irrigated beginning in 2003. In addition, the 68,000 acres retired under the No Action Alternative are returned to irrigated agricultural production.

- Irrigation system improvements and practices remain the same as existing conditions.
- Simulated Westlands annual groundwater pumping is reduced by 7 percent.
- In the GDA, seepage reduction projects decrease water-table recharge by 4,200 AF/year.
- Regional drainwater recycling continues in the GDA and is implemented in Westlands. Drainwater recycling displaces surface-water supplies and, therefore, does not impact irrigation recharge rate. However, recycling can increase irrigation-water salinity.
- About 28,000 acres of reuse and treatment facilities begin operation in 2005. Irrigation recharge beneath the reuse fields was assumed to be 1 foot/year. The direct application of drainwater increases salt loads in irrigation water applied to these lands.
- Almost 5,100 acres of evaporation ponds are required to reduce drainwater volume. We assumed pond leakage was negligible.

G1.3.2.3 Environmental Impacts

No Action

Under the No Action Alternative, groundwater changes are affected primarily by (1) the cessation of drainage within the GDA after 2009 and (2) 68,000 acres of land retired in the Westlands. Without drainage in the GDA, the simulated net water-table rise beneath its drainage-impacted area averages 1.9 feet. In contrast, land retirement in Westlands lowers the water table beneath the lands retired. On the average, the simulated water table beneath the Westlands drainage problem area decreased by 1.1 feet. However, the water-table effect from land retirement is negligible beneath irrigated lands upgradient and adjacent to the retired lands (Belitz and Phillips 1994).

- *Bare-soil evaporation*. A rising water table increases the simulated evaporation rate. In the GDA, the simulated evaporation rate increases from 0.27 foot/year in 2001 to 0.53 foot/year in 2050 (a net increase of 0.26 foot/year). This impact was considered a significant adverse environmental impact in the GDA. In Westlands, the simulated evaporation rate increases from 0.20 to 0.28 foot/year (a net increase of 0.08 foot/year). This impact was considered a significant adverse environmental impact in Westlands.
- *Area affected by shallow water table*. A rising water table increases the simulated area underlain by a water table within 7 feet of land surface. In the GDA, the area underlain by the shallow water table increased from 134 to 145 square miles from 2001 to 2050 (a net increase of 11 square miles). This increase in area was considered a potentially adverse environmental impact. In Westlands, the area underlain by the shallow water table increased from 235 to 361 square miles (a net increase of 126 square miles). This area increase was considered a significant adverse environmental impact.
- *Groundwater salinity.* Under the No Action Alternative, increased bare-soil evaporation without drainage to remove salts will increase soil and groundwater salinity. In the GDA, without the Grassland Bypass Project agreement, recycling and reuse will increase the salinity of the applied irrigation water and increase soil and groundwater salinity levels. For example, HydroFocus estimated a 10 percent groundwater salinity increase in the GDA after 9 years of conditions similar to the No Action Alternative (Reclamation 2001, Appendix D).

If undiluted drainwater is applied directly, especially under undrained conditions, the expected salinity increase is more dramatic. For example, HydroFocus' calculations indicated that irrigation with undiluted drainwater caused soil salinity to more than double under undrained conditions. The above salinity increases were considered significant adverse impacts. The shallow wellwater sample results will be utilized to empirically assess groundwater salinity changes and improve estimates for initial drainwater quality.

- *Drinking water supply.* Groundwater supplies for the City of Mendota reportedly have the potential to be impacted. Water quality data for City of Mendota well number 5 indicate increasing trends in salinity in the late 1990s, which may be attributed to westward movement of shallow, saline groundwater. If drainage is not provided and irrigation continues, high salinity groundwater impacts to wells may increase.

<u>Out-of-Valley</u>

Under the Out-of-Valley alternatives, the average net simulated water-table rise beneath the GDA drainage service area averaged 0.2 foot. Beneath the Westlands drainage service area, the average net simulated water-table rise is 1.2 feet.

- *Bare-soil evaporation*. In the GDA, the simulated evaporation rate increases from 0.27 foot/year in 2001 to 0.29 foot/year in 2050 (a net increase of 0.02 foot/year). In Westlands, the simulated evaporation rate decreased from 0.20 foot/year to 0.18 foot/year during the same time interval. These evaporation rate changes were considered to have no environmental impact and the Out-of-Valley alternatives are, therefore, beneficial relative to the No Action Alternative.

- *Area affected by shallow water table.* A rising water table increases the simulated area underlain by a water table within 7 feet of land surface. In the GDA drainage service area, the area underlain by the shallow water table increased from 134 to 143 square miles during the period 2001 to 2050 (a net increase of 9 square miles). In the Westlands drainage service area, the simulated area underlain by the shallow water table increased from 235 to 378 square miles (a net increase of 143 square miles). The simulated area changes in the GDA were considered a potentially adverse impact, and the area changes in Westlands a significant adverse environmental impact. The simulated area increases in Westlands are significantly greater than under the No Action Alternative conditions and, therefore, the Out-of-Valley alternatives provided an adverse impact relative to the No Action Alternative.

- *Groundwater salinity*. Under the Out-of-Valley alternatives, soil and groundwater salinity can increase as a result of drainwater recycling, but the increase will be less than estimated for the No Action Alternative. For example, groundwater salinity was estimated to increase from 5.9 to 6.1 dS/m after 9 years of drainwater recycling in the GDA (a net increase of about 3 percent) (Reclamation 2001, Appendix D). The Out-of-Valley alternatives are, therefore, considered to have a beneficial impact on groundwater salinity relative to the No Action Alternative.

  Beneath the reuse facilities, where undiluted drainwater is applied directly to crops, the expected salinity increase is more dramatic. For example, salinity calculations for fields within the GDA indicated that irrigation with undiluted drainwater caused groundwater salinity to increase by more than 40 percent. Although these salinity increases represent significant adverse impacts, they are limited to relatively small areas and are not irreversible.

Impacted soils could be reclaimed and saline shallow groundwater removed if an alternative means of salt disposal becomes available.

In-Valley

In the GDA drainage service area, the average simulated net water-table rise was 0.1 foot during the period 2001–2050. Beneath the Westlands drainage service area, the average net simulated water-table rise was 1.2 feet.

- *Bare-soil evaporation*. In the GDA, the simulated evaporation rate increases from 0.27 foot/year in 2001 to 0.29 foot/year in 2050 (a net increase of 0.02 foot/year). In Westlands the simulated evaporation rate decreased from 0.20 to 0.18 foot/year during the 2001-2050 period. These evaporation rate changes were considered to have no environmental impacts and the In-Valley Disposal Alternative is, therefore, beneficial relative to the No Action Alternative.
- *Area affected by shallow water table*. The rising water table increases the simulated area underlain by a water table within 7 feet of land surface. In the GDA, the simulated area underlain by the shallow water table increased from 134 square miles in 2001 to 143 square miles in 2050 (a net increase of 9 square miles). In Westlands the simulated area underlain by the shallow water table increased from 235 to 384 square miles (a net increase of 149 square miles). The simulated area change beneath the GDA was considered to have no impact, and in Westlands the water-table change was considered a significant adverse environmental impact. The simulated area increases are greater than under the No Action Alternative conditions and, therefore, the In-Valley Disposal Alternative provided an adverse impact relative to the No Action Alternative.
- *Groundwater salinity*. Under the In-Valley Disposal Alternative, soil and groundwater salinity can increase as a result of drainwater recycling, but the increase will be less than estimated for the No Action Alternative. For example, groundwater salinity was estimated to increase from 5.9 to 6.1 dS/m after 9 years of conditions similar to the In-Valley Disposal Alternative (a net increase of about 3 percent). The In-Valley Disposal Alternative is therefore considered to have a beneficial impact on groundwater salinity relative to the No Action Alternative.

  Beneath the reuse facilities, where undiluted drainwater is applied directly to crops, the expected salinity increase is more dramatic. For example, salinity calculations for fields within the GDA indicated that irrigation with undiluted drainwater caused groundwater salinity to increase by more than 40 percent. Although these salinity increases represent significant adverse impacts, they are limited to relatively small areas and are not irreversible. Impacted soils could be reclaimed and saline shallow groundwater removed if an alternative means of salt disposal becomes available.

G1.3.2.4 Impact Summary

Table G1-18 summarizes groundwater and soil impacts. The impacts are evaluated relative to the No Action Alternative and existing conditions.

Table G1-18
Estimated Environmental Impact Summary Relative to the No Action Scenario

Anticipated Environmental Effect	No Action (*Compared to Existing Conditions)*	Out-of-Valley (*Compared to No Action)* Delta Discharge Chipps Island	Delta Discharge Carquinez Strait	Ocean Discharge Point Estero	In-Valley (*Compared to No Action)*
Bare-soil Evaporation	Significant Adverse Impact	Beneficial Impact	Beneficial Impact	Beneficial Impact	Beneficial Impact
Area affected by shallow water table	Significant Adverse Impact	Adverse Impact	Adverse Impact	Adverse Impact	Adverse Impact
Groundwater salinity	Significant Adverse Impact	Beneficial Impact	Beneficial Impact	Beneficial Impact	Beneficial Impact

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ATTACHMENT G1.1

MIKE 21 MODEL CALIBRATION

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Acronyms

AD	MIKE 21 advection-dispersion module
HD	MIKE 21 hydrodynamic module
ME	MIKE 21 heavy metals module
ppt	part(s) per thousand
Se	selenium
TDS	total dissolved solids
USGS	U.S. Geological Survey

G1.1.1 Overview of Method

The effect of the proposed San Luis Drain discharge on total dissolved solids (TDS) and selenium (Se) concentrations in northern San Francisco Bay and the Delta were modeled in this study using the MIKE 21 software developed by the Danish Hydraulic Institute (DHI 1998). MIKE 21 consists of three linked modules. The first is a hydrodynamic module (MIKE 21 HD) that solves the time-dependent, vertically integrated equations of continuity and conservation of momentum in two horizontal directions. The second is an advection-dispersion module (MIKE 21 AD) that uses the hydraulic flow fields from MIKE 21 HD to calculate the transport of conservative substances in the water column. The last is a heavy metals module (MIKE 21 ME) that uses the computations from MIKE 21 HD and MIKE 21 AD to calculate sediment transport and nonconservative mass transfer (i.e., sorption) between dissolved metals and suspended or benthic sediment.

G1.1.2 MIKE 21 HD Module Calibration

Introduction

The hydrodynamic component of the MIKE 21 modules was previously calibrated to accurately represent tides and currents in San Francisco Bay (URS 2002). Consequently, the only modifications required in this study were supplying appropriate hydrodynamic input parameters for the modeled water years (1977 for MIKE 21 AD TDS modeling and 1997 for MIKE 21 ME Se modeling).

Hydrodynamic Input Parameters

Hydrodynamic input parameters include bathymetry, hydrographic boundary conditions (e.g., inflows and tides), wind velocities, and source/sink flows.

The bathymetry modeled in this study is displayed on Figure G1-3 in Appendix G1 using 0.4-km^2 rectangular grid cells and a NGVD 1929 vertical datum. The Delta region east of Decker and Bradford islands on the figure were included as "boxes" with volumes approximating the Sacramento and San Joaquin Delta systems, respectively.

Boundary flows for the Delta for 1977 were obtained from the Flow Science Fischer-Delta Model, after subtracting the tidal component. For 1997, outflow was specified as the average daily flow rate estimated by the California Department of Water Resources using the DAYFLOW program (http://www.iep.water.ca.gov/dayflow). Water elevations at the Pacific Ocean boundary were obtained from the National Oceanic and Atmospheric Administration tide station located at Point Reyes for both water years.

Wind speed and direction were obtained from the National Climatic Data Center station at San Pablo Bay owing to its proximity to the project location. Although hourly winds from the 1990 Dry Season were used for 1977, the strong daily and seasonal dependence was captured using this approach. Wind speed and direction for 1997 were obtained using corresponding data.

Flows for tributary sources were estimated for both water years from U.S. Geological Survey (USGS) stream gage measurements using a methodology described by Daum and Davis (2000). First, 70 watershed drainage areas in the Bay Area were delineated using a Geographic

Information System. USGS stream gauges in a number of creeks were then used to estimate flows in nearby streams by normalizing flows by watershed area. Thirty-six publicly owned treatment works and industrial facilities were also included in the model, using flows reported in 1997 National Pollutant Discharge Elimination System self-monitoring reports.

G1.1.3 MIKE 21 AD Module Calibration

Introduction

MIKE 21 AD was used to predict changes in TDS. Because the hydrodynamic components of this module were previously shown to accurately represent tides and currents in the Bay (URS 2002), only those parameters governing advection and dispersion of dissolved substances required additional calibration.

Due to the large computational time required to solve the two-dimensional equations in MIKE 21, a 6-month simulation period during the 1977 Dry Season was selected for calibration. By choosing the period with the lowest Delta flows on record, the uncertainty associated with modeling extreme hydrologic events was minimized.

Advection-Dispersion Input Parameters

Inputs to the MIKE 21 AD module include initial TDS fields, model boundary concentrations, and source/sink discharge concentrations.

The initial salinity field was created utilizing the data collected by the USGS along the main channel in the Bay on June 8, 1977.

Model boundary concentrations were specified as 33 parts per thousand (ppt) for the Pacific Ocean, 0.1 ppt for the Sacramento River, and 0.8 ppt for the San Joaquin River. The latter value was based on correlations developed among electrical conductivity, flow, and salinity at the Vernalis monitoring station.

TDS concentrations in tributary, publicly owned treatment work, and industrial facility flows were set to zero.

MIKE 21 AD Calibration Parameters

The primary calibration parameters in MIKE 21 AD are spatially varying dispersion coefficients. The values used in this study were 300 m^2/s for the Central and North bays, and 10 m^2/s in the South Bay, similar to coefficients reported by Monismith et al. (2001). The higher constants required to achieve calibration in the North Bay are related to the large vertical shear associated with stratification, an effect that cannot be resolved by a depth-averaged model.

MIKE 21 AD Calibration Results

Predicted and observed TDS at the 18 USGS monitoring stations displayed on Figure G1-3 in Appendix G1 are shown on Figures G1-4a and G1-4b for four 1977 cruises. TDS is well calibrated by the model and no consistent bias occurs at any station. This result is reflected in Table G1.1-1, which shows that differences between predicted and observed TDS in the North and Central bays are less than 1 mg/L.

Table G1.1-1
Statistics on TDS–Water Year 1977 Calibration

Bay Segment	Number of Data Points	Total Dissolved Solids (mg/L)				
		Mean Concentration		Median Concentration		Average RMS Diff.
		Predicted	Observed	Predicted	Observed	
Suisun Bay	27	17	18	17	18	0
San Pablo Bay	12	29	29	29	30	0
Central Bay	12	32	32	32	33	0

G1.1.4 MIKE 21 ME Module Calibration

Introduction

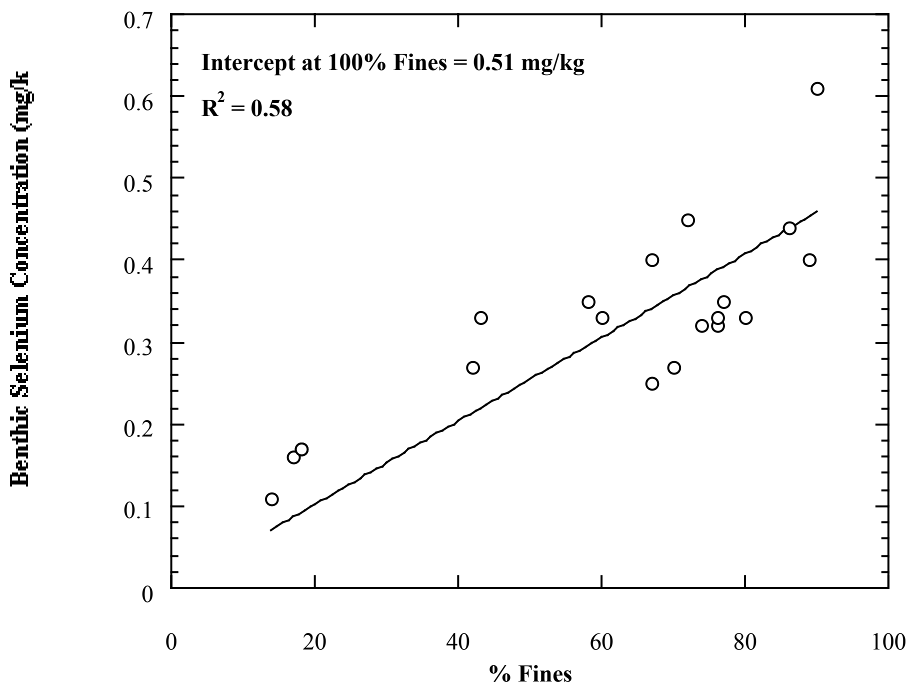
MIKE 21 ME was used to predict changes in Se concentrations. Because the hydrodynamic and sediment transport components of this module were previously shown to accurately represent tides, currents, and suspended sediment concentrations in the Bay (URS 2002), only those parameters governing porewater and sorptive fluxes required additional calibration.

Due to the large computational time required to solve the two-dimensional equations in MIKE 21, a 6-month simulation during 1997 was chosen for calibration. This period was chosen to coincide with the 1997 Regional Monitoring Program (RMP) sampling schedule for the Bay.

Heavy Metal Input Parameters

Inputs to the MIKE 21 ME module include initial Se concentrations, model boundary concentrations, and source/sink discharge concentrations.

Initial benthic sediment Se concentrations for most of the Bay were determined from benthic surveys conducted by the Regional Monitoring Program for Trace Substances (SFEI 1994-1998). Because the MIKE 21 ME module can only model one grain-size fraction (i.e., mud), average benthic concentrations for each San Francisco Bay monitoring station were first plotted against the average fraction of sediments that are fine-grained. A linear least squares regression was then fit to the data, with the intercept at 100 percent fines used to represent the initial benthic concentration. As shown on Figure G1.1-1, this intercept is 0.5 mg/kg, with a correlation coefficient of 0.58. For the San Joaquin Delta, a value of 1 mg/kg was used based on average measurements at Vernalis (Luoma and Presser 2000).



URS	Job No. 17324004	Average Benthic Selenium Concentrations and Average Fines at Regional Monitoring Stations (SFEI 1994-1998)	FIGURE G1.1-1
	San Luis Drainage Feature Re-evaluation		

Initial porewater Se concentrations were assumed to be 0.3 μg/L, based on depth-averaged measurements in two mudflats of Carquinez Strait (Zawislanski and McGrath 1998). Also, initial adsorbed concentrations in surface waters were obtained by assuming suspended sediment has the same Se concentration as the underlying benthic sediment. By making this assumption, initial dissolved Se concentrations in surface water were calculated using the equilibrium distribution coefficients represented by the calibrated adsorption and desorption rate constants described below.

At both the Pacific Ocean and Sacramento River boundaries, dissolved and adsorbed Se concentrations were assumed to be 0.06 μg/L and 0.2 mg/kg, respectively. For the Pacific Ocean, dissolved concentrations were based on measurements by Cutter and Bruland (1984), and adsorbed concentrations from equilibrium distribution coefficients determined during calibration. For the Sacramento River boundary, dissolved Se concentrations were based on measurements of Cutter and San Diego-McGlone (1990), and adsorbed concentrations from estimates of Luoma and Presser (2000). Finally, time-varying dissolved and adsorbed concentrations at the San Joaquin River boundary were based on measurements of total Se at Vernalis (CCVRWQCB 1998) and an assumed equilibrium distribution coefficient of 1,000 L/kg (Luoma and Presser 2000).

Total Se concentrations in tributary sources during storm events were obtained from a land-use summary of the Bay Area Stormwater Management Agencies Association data set (Daum and Davis 2000), where values of half the detection limit were used for nondetect measurements. Partitioning between adsorbed and dissolved Se for storm events was performed using the same equilibrium distribution coefficients calibrated for the ambient Bay. Total Se concentrations during dry-weather flows (defined as being less than twice the July–August baseflow) were reduced from storm event concentrations to account for lower suspended Se concentrations.

MIKE 21 ME Calibration Parameters

The primary calibration parameters in the MIKE 21 ME module are rate constants for porewater Se diffusion and Se sorption. Porewater diffusion rate constants were assumed to be 6×10^{-6} cm^2/sec based on estimates for other metals (Rivera-Duarte and Flegal 1997). A desorption rate constant of 0.8 day^{-1} was taken from the mean value measured by Glegg et al. (1988). Finally, an adsorption rate constant of 0.003 L/mg/day was determined through a calibration procedure where differences between predicted and measured dissolved Se concentrations in the Bay were graphically minimized. The final equilibrium distribution coefficient of 3,750 L/kg, calculated by dividing the adsorption rate constant by the desorption rate constant, is between the average (4,000 L/kg) and median (3,400 L/kg) values determined during the RMP for 1997.

MIKE 21 ME Dissolved Selenium Calibration Results

Measured and predicted dissolved Se concentrations at the 12 RMP monitoring stations displayed on Figure G1-3 in Appendix G1 are shown as time series on Figures G1-5a and G1-5b for the calibration year 1997. Dissolved Se concentrations in the North and Central bays generally agree with measured concentrations, although the natural variability in concentration at any particular monitoring station is greater than the model predicts. Average root-mean-squared differences in the region selected for alternatives analysis are 0.02 μg/L (Table G1.1-2). The largest errors in model predictions occur for the South and Central bays, outside of the region analyzed in this study.

Table G1.1-2
Statistics on Dissolved Selenium–Water Year 1997 Calibration

Bay Segment	Number of Data Points	Dissolved Selenium (µg/L)				
		Mean Concentration		Median Concentration		Average RMS Diff.
		Predicted	Observed	Predicted	Observed	
Suisun Bay	13	0.11	0.12	0.09	0.12	0.02
San Pablo Bay	9	0.15	0.17	0.17	0.16	0.01
Central Bay	8	0.13	0.09	0.11	0.10	0.02
South Bay	9	0.16	0.22	0.16	0.15	0.05
Lower South Bay	5	0.17	0.54	0.17	0.38	0.22

MIKE 21 ME Adsorbed Selenium Calibration Results

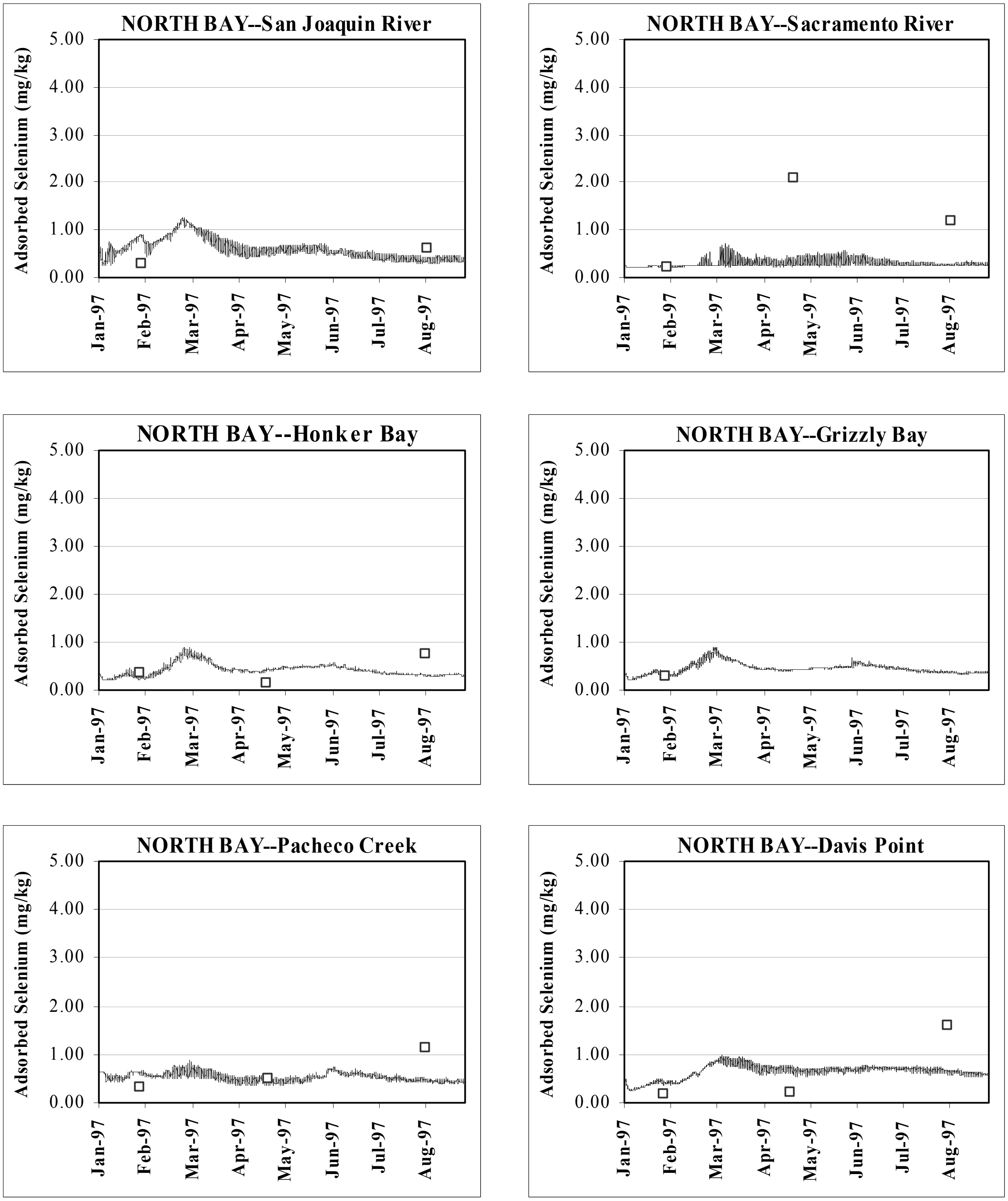
Measured and predicted adsorbed Se concentrations on suspended sediment at the 12 RMP monitoring stations displayed on Figure G1-3 in Appendix G1 are shown as time series on Figures G1.1-2a and G1.1-2b for the calibration year 1997. Adsorbed concentrations on the plots were screened to remove values associated with suspended sediment concentrations less than 10 mg/L. This filtering of data was necessitated by the inaccuracies involved in measuring adsorbed concentrations when little suspended sediment is available, and the bias towards high adsorbed Se concentrations shown on Figure G1.1-3.

As illustrated on Figure G1.1-4, the variability in predicted values is considerably less than the measured variability; however, the model is consistent with the average adsorbed selenium concentration for the data. Predictions are closest to observations in the North Bay (Table G1.1-3), with root-mean-squared differences less than 0.2 mg/kg. Predicted concentrations deviate the most from observations in the Central and South bays, although relatively few data points exist to draw distinctions.

Table G1.1-3
Statistics on Adsorbed Selenium–Water Year 1997 Calibration

Bay Segment	Number of Data Points	Adsorbed Selenium (mg/kg)*				
		Mean Concentration		Median Concentration		Average RMS Diff.
		Predicted	Observed	Predicted	Observed	
Suisun Bay	12	0.40	0.66	0.35	0.42	0.19
San Pablo Bay	8	0.54	0.49	0.58	0.30	0.15
Central Bay	3	0.47	3.07	0.42	3.50	1.65
South Bay	3	0.59	1.56	0.58	1.23	0.73
Lower South Bay	5	0.64	4.19	0.64	1.00	3.46

*Based on measured TSS > 10 mg/L



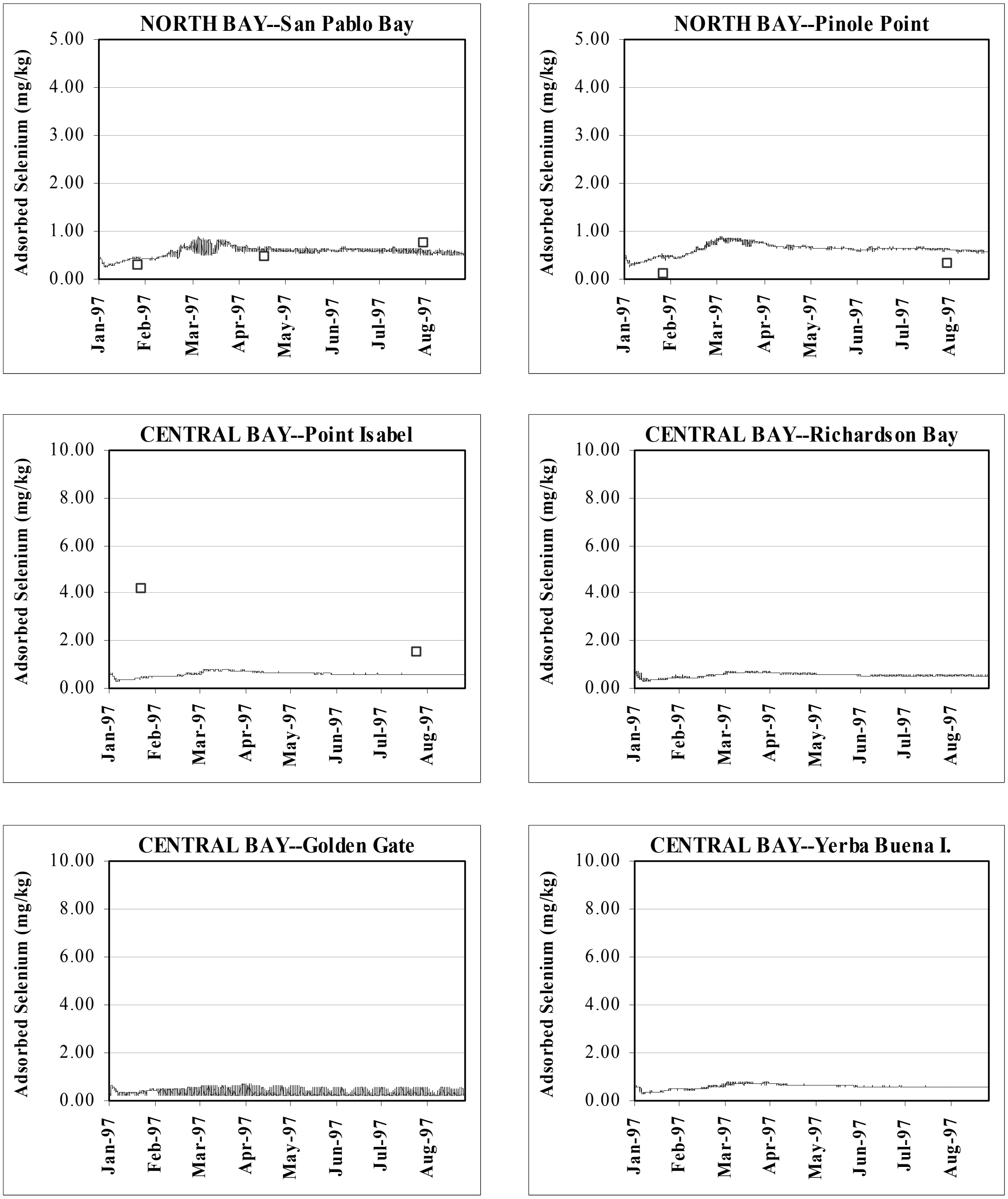
URS

Job No. 17324004

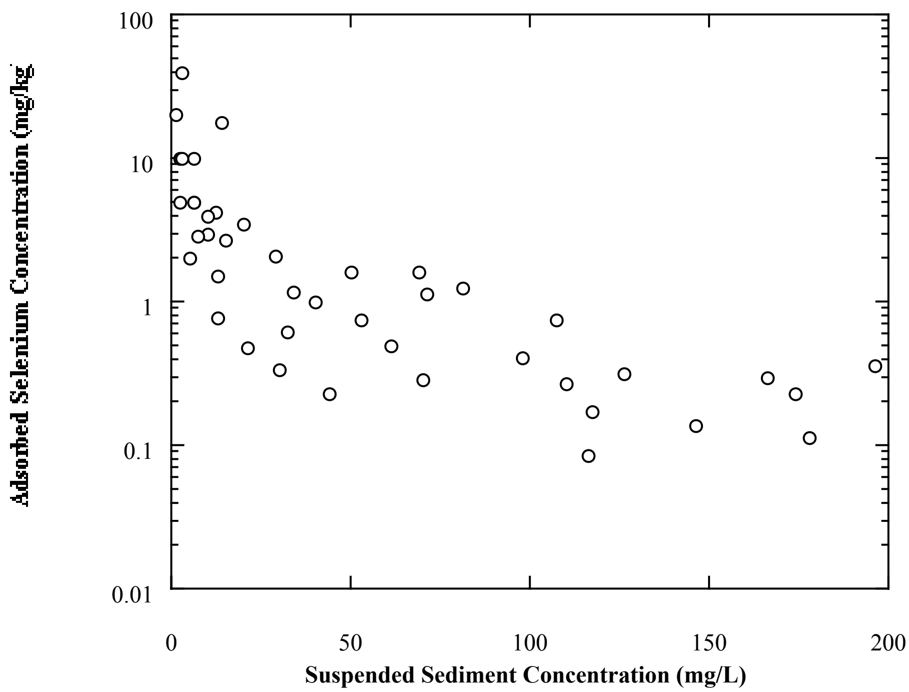
San Luis Drainage Feature Re-evaluation

MIKE 21 North Bay Adsorbed Selenium Calibration Results For Water Year 1997 (January through August RMP Cruises)

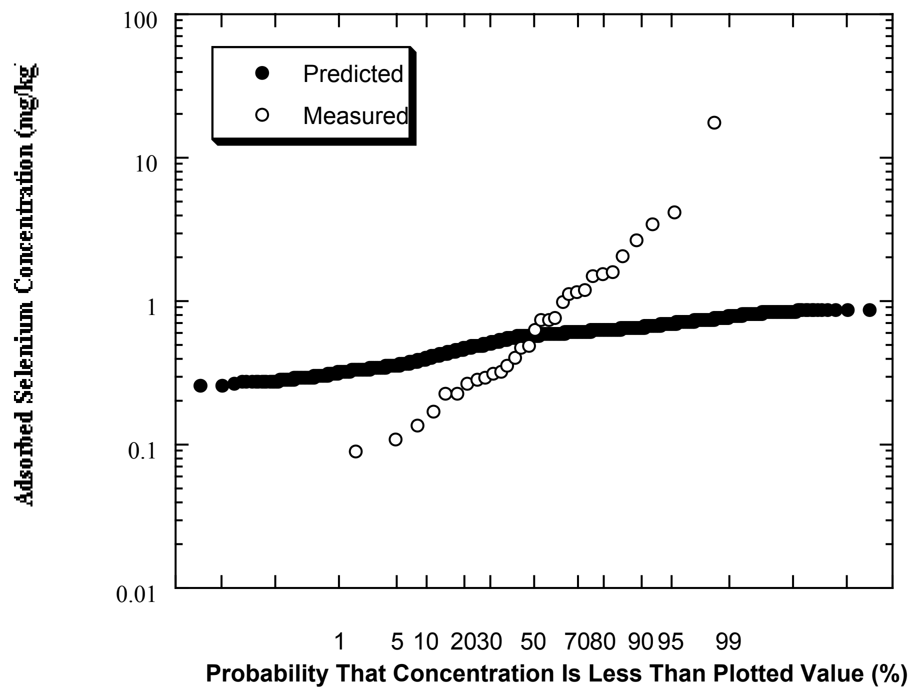
FIGURE G1.1-2a



URS	Job No. 17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 San Pablo Bay and Central Bay Adsorbed Selenium Calibration Results For Water Year 1997 (January through August RMP Cruises)	FIGURE G1.1-2b



URS	Job No. 17324004 San Luis Drainage Feature Re-evaluation	Adsorbed Selenium and Suspended Sediment Concentrations at Regional Monitoring Stations For Water Year 1997 (SFEI 1998)	FIGURE G1.1-3



URS	Job No. 17324004 San Luis Drainage Feature Re-evaluation	MIKE 21 Predicted and RMP Measured Probability of Exceedance of Adsorbed Selenium Concentrations for Water Year 1997	FIGURE G1.1-4

G1.1.5 References

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